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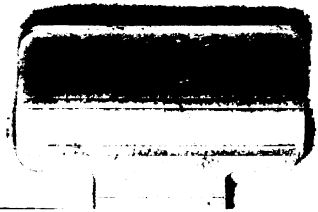

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Swingle's Catechism of Steam, Gas, and Electrical Engineering

INTRODUCTION

The constantly increasing demand for information in a condensed form, pertaining to engineering topics has induced the author to prepare this book, with a view of assisting his brother engineers in their search for just the information that they are looking for, and especially when they are in a hurry, and do not have much time to look for it, as, for instance, in an emergency due to a breakdown, the Catechism of Steam, Gas, and Electricity will be found to be an invaluable aid, for the reason that it covers practically the entire field of Stationary Engineering, including not only Steam Boilers and Engines, but, in addition, Steam Turbines, Gas Engines, and Gas Producers, Air Compressors, Refrigeration and Ice Making, Elevators, both Electric and Hydraulic, and finally, the subjects of Electricity and Electric Machines, Dynamos, Motors, etc.

The necessity for thorough and complete examinations regarding the qualifications of men asking to be entrusted with the care and operation of power generators, whether steam, gas or electrical, is now universally recognized, and as a consequence, all large cities and towns, and a large number of states, have license laws, requiring engineers and electricians to pass these examinations before being granted license permitting them to take charge of and operate such

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machinery. To those contemplating the taking of such examinations, the questions and answers following will prove to be a most valuable helper, as it furnishes the much sought-for information in plain, easily understood language, the answers being condensed in such form as to enable the applicant for license to memorize them without any difficulty whatever, and thus be able to qualify himself for the position sought for. This Catechism thus serves the double purpose of being an assistant to the working engineer, and also a helper to the man who aspires to become an engineer.

CALVIN F. SWINGLE.

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Types of Boilers

1. What types of boilers are most commonly used for stationary work?

Ans. The horizontal tubular boiler and the water-tube boiler.

2. Describe in general terms the horizontal tubular boiler.

Ans. It consists of a shell having tubes of small diameter, extending from head to head.

These tubes are located in the water space.

3. What is their function?

Ans. To supply a passageway to the stack for the hot gases from the furnace.

4. Does the water in the boiler receive heat from these tubes?

Ans, It certainly does.

5. Describe the route taken by the smoke and hot gases in the operation of a tubular boiler.

Ans. From the furnace, located under the front end of the boiler, the gases pass under and along the sides of the shell, back to the rear end, the upper part of which is arched over. The route is here reversed, and the products of combustion return through the flues towards the front end and thence through the breeching into the stack.

6. Is this type of boiler economical in the burning of fuel?

Ans. It can be made so if properly set and handled in operation.

7. Describe in a general way the water-tube boiler.

Ans. It consists of a set, or sets of tubes 3 to 4 inches in diameter, sometimes vertical, and sometimes inclined,

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and connected at the top to a steam drum, and at the bottom to a mud drum.

8. What advantages as regards circulation of the water has the water tube boiler?

Ans. It provides for a free circulation.

9. Name another advantage connected with the water tube boiler.

Ans. The margin of safety from dangerous explosions.

10. Why is this?

Ans. Because if one or more tubes gives way the pressure is relieved.

11. What precautions should be observed in the design and construction of a boiler?

Ans. The best materials should be used, the boiler should be simple in design, and the workmanship should be perfect.

12. Where should the mud drum be located?

Ans. In a place removed from the action of the fire.

13. What should be the capacity of the boiler relative to its work?

Ans. It should have a steam and water capacity sufficient to prevent any fluctuation in either the steam pressure, or the water level, if properly fed.

14. Why should the water in a boiler circulate freely and constantly?

Ans. In order to maintain all parts at as near the same temperature as possible.

15. What should the strength of a boiler be, relative to the strain it is liable to be subject to?

Ans. It should have a great excess of strength,

16. Is a combustion chamber an advantage to a boiler?

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Ans. It is, in order to complete the combustion of the gases before they escape to the chimney.

17. How should a boiler be arranged with regard to cleaning?

Ans. All parts should be easily accessible for cleaning and repairs.

18. What type of boiler is the Cahall?

Ans. It is a water-tube boiler.

19. Is it vertical or horizontal?

Ans. It is built either way.

20. What form of Cahall is generally used in central power stations?

Ans. The horizontal form.

20a. What is the range of pressures that these boilers are built for?

Ans. From 160 to 500 pounds per square inch,

21. Describe the method of constructing the joints.

Ans. The sheets are beveled on the edges, bent into shape, and rivet holes drilled after bending.

22. What is gained by so doing?

Ans. Absolutely round rivet holes and no crystallization.

23. What type of riveted joint is used on the higher pressure boilers?

Ans. Triple riveted, double strapped.

24. How are the tubes connected to the steam drum in the Cahall boiler?

Ans. By nipples connected to saddles on the drum.

25. Does this boiler rest upon the brick work?

Ans. It does not, but is suspended free from the masonry.

26. What advantage is there in this style of setting?

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Ans. The entire structure is free to expand or contract without causing any strains on either boiler or brick work.

27. Describe the Heine boiler.

Ans. It consists of one, and sometimes two shells on drums resting upon water legs riveted to each end. These water legs are connected by horizontal tubes. The water fills the tubes, water legs, and partially fills the shell, leaving the upper portion for steam space.

28. In the setting does this boiler occupy a horizontal position?

Ans. No. The shell and tubes have an incline of one inch in twelve from front to rear.

29. What provision is made for cleaning and repairing the tubes?

Ans. Hand-holes are located in the head plates opposite each tube.

30. How are these hand-holes closed?

Ans. In the ordinary way, by plates.

31. Where is the mud drum located in the Heine boiler?

Ans. Inside the shell, near the bottom.

32. How is the Heine boiler supported in the setting?

Ans. The front or fixed end rests upon cast iron columns. The rear water leg upon rollers.

33. Describe in brief the Babcock & Wilcox boiler.

Ans. It is composed of wrought iron tubes, placed in an inclined position, and connected with each other, and with a horizontal steam, and water drum by vertical headers.

34. Where is the mud drum in this boiler?

Ans. In the rear, and connected to the lowest part of the boiler.

35. What provision is made for cleaning the tubes in the Babcock & Wilcox boiler?

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Ans. Through hand-holes in the headers, opposite each tube.

36. How is this boiler supported in the setting?

Ans. It is suspended from wrought iron girders, entirely independent of the brick work.

37. Describe in general terms the Stirling boiler,

Ans. It consists of three upper steam drums, each being connected by a number of tubes to a lower or mud drum.

38. How are the steam spaces connected?

Ans. By shorter tubes.

39. How is the boiler supported?

Ans. On a structural steel frame work.

40. What provision is made for expansion and contraction of the tubes?

Ans. They are slightly curved near the ends.

41. How are the hot gases directed in their course from furnace to stack?

Ans. By means of fire brick baffle walls.

42. How is the interior of this boiler cleaned?

Ans. Four manholes are provided in the drums, by which access to the interior of both the drums and tubes is obtained.

43, What type of boiler is the Maxim boiler?

Ans. It is a water-tube boiler consisting of two drums, one above the other, connected by tubes.

44. Describe the tubes.

Ans. Each tube has two bends, thus providing for unequal expansion or contraction.

45. How is the heating surface of the Maxim boiler arranged?

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Ans. It is so arranged that the current of heated gases is made to travel three times the length of the tubes, the direction of the current being changed seven times in its route from furnace to stack.

46. What can be said of the Bigelow-Hornsby water-tube boiler?

Ans. Owing to the flexible form of its construction it is possible to build it in very large units, 2,000 horsepower and upwards.

47. What peculiar feature makes this possible?

Ans. Each section is independent of its neighbor, except the nipples connecting with the steam drum, and the equalizing nipples connecting the bottom drums of the rear sections.

48. How is the boiler supported?

Ans. Entirely from overhead beams,

49. What percentage of the heating surface do the tubes of the front unit comprise?

Ans. More than 12 per cent.

50. Where is the feed water first admitted?

Ans. Into the bottom drum of the rear unit.

51. Describe the course of the feed water.

Ans. The feed water is admitted into the bottom drum of the rear unit, and is advanced gradually from the coldest to the hottest portion of the boiler.

52. How is the speed of the feed water up the rear unit regulated?

Ans. By the amount of steam generated, ample time being permitted for scale forming matter to be deposited in the bottom drum of this unit.

53. Where does the liberation of steam take place?

Ans. In the upper drum.

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54. What can be said of this boiler regarding the utilization of the heat?

Ans, It is baffled so that the products of combustion are carried uniformly over the heating surfaces in thin layers, the baffle plates serving to guide the gases through in substantially uniform passages.

55. To what factor of safety is the Bigelow-Hornsby boiler built?

Ans. Five for 200 pounds working pressure.

56. Describe in brief the Wickes vertical water-tube boiler.

Ans. It consists of two cylinders joined together endways by straight tubes, and erected in a vertical position.

57. What can be said of the top cylinder?

Ans. It is the longer, and is designated the steam drum.

58. What about the bottom cylinder?

Ans. It is the shorter, and is designated the mud drum. Both cylinders vary in dimensions as to diameter and length, according to the power required of the boiler.

59. Where are the manholes of the Wickes boiler?

Ans. One is placed in the convex head of the steam drum; there are also a number of hand-holes in this head. A manhole is also placed in the lower or mud drum, near the floor, thus permitting access to the top and bottom of the boiler,

60. How are these tubes divided?

Ans. By heavy fire-clay tile these tubes are divided into two compartments. Those tubes in the front compartment are called the "risers" and those in the rear the "downcomers."

61. What can be said of the heat in its double passage?

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Ans. It surrounds completely, and closely the tubes in both compartments.

62. Where is the water line in this boiler?

Ans. At a sufficient height in the steam drum to insure the complete submersion of all the tubes.

63. How is the brick work setting of the Wickes water-tube boiler arranged?

Ans. It is independent of the weight of the boiler, and free to expand or contract.

64. Describe briefly the design of the Atlas water-tube boiler.

Ans. It consists mainly of three drums and two water legs extending crosswise, while the tubes extend lengthwise.

65. What is the original feature in the design of the water legs?

Ans. They are formed by the continuation of front and rear shell plates.

66. What other valuable feature is claimed for this boiler?

Ans. After the steam leaves the vessels containing water it is passed through a series of superheating tubes, and is superheated.

67. Describe the course of the feed water.

Ans. It is fed first into the purifier, whence it overflows into the rear drum and down into the rear leg, thence through the inclined tubes to the front leg, thence up into the front drum, where the steam is liberated and carried through superheating tubes to the steam drum.

68. What are the facilities for cleaning the water tubes of this boiler?

Ans. An individual hand-hole is located opposite each end of each water tube.

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69. How is the interior of each of the three cross drums reached?

Ans. Through a large manhole in each end.

70. Describe briefly the design and construction of the Marzolf water-tube boiler.

Ans. It consists of three drums connected with each other in triangular form. Drum A directly over the fire is connected by tubes with drum B above it, and with drum C in the rear and slightly below it. Drum C, which is the mud drum, is also connected with drum B. The tubes are each slightly bent. The steam is collected in drum B, which is maintained about one-third full of water.

71. Describe in brief the action of the heat upon this boiler.

Ans. It acts first upon the water in drum A over the furnace, then by means of a baffle wall it is carried along the inclined tubes to drum B, where it is deflected and carried down along other inclined tubes to drum C, thence to the stack.

71. How are the products of combustion caused to act upon the lower bank of tubes?

Ans. By means of baffle walls located in the rear of the furnace.

72. At what point in this boiler is the feed water admitted?

Ans. At the lowest point, viz., the mud drum.

73. What are the principal advantages claimed for the Duplex water-tube boiler?

Ans. Delivery of superheated steam; the removal of steam from the boiler at a point where there is no ebullition; the drums not exposed to the direct action of the fire.

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74. Describe in brief the design of this boiler.

Ans. Two upper steam drums connected by tubes, a mud drum at the bottom and rear which is connected to the upper drums by headers and short nipples. The tubes are inclined 20 degrees to insure rapid and positive circulation.

75. How is this boiler supported?

Ans. Upon a heavy steel framework.

76. What is the leading feature in connection with the Erie City water-tube boiler?

Ans. The three banks of tubes are practically vertical, connected to upper, and lower drums, and spaced so that any one of them may be cut out for repairs without interfering with the others.

77. How do the products of combustion act upon this boiler?

Ans. The baffling is arranged to pass three times across the tubes, and at each end of the upper drum is a dry chamber.

78. Describe in brief the best method of supporting horizontal tubular boilers.

Ans. By means of hangers suspended from I beams, supported by cast iron columns. This takes the weight off the side walls.

79. What three principles should govern the design and construction of steam boilers?

Ans. First: They should be absolutely safe. Second: They should be economical in the consumption of fuel. Third: They should be capable of furnishing dry steam.

80. What is meant by the term tensile strength as applied to boiler material?

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Ans. The number of pounds of pull that would be required to break a bar of the material in the direction of its length.

81. What is liable to occur in case the tensile strength is too high?

Ans. Cracking of the sheets, also certain changes in the physical properties of the metal.

82. Which are the stronger, punched or drilled plates?

Ans. If the material is good soft steel, punched plates show a greater shearing resistance.

83. What should be the tensile strength of rivet iron?

Ans. About 60,000 pounds per square inch.

84. What is a good test for a $\frac{5}{8}$-inch rivet?

Ans. It should stand being doubled up and hammered together cold without being fractured.

85. What is the shearing resistance of iron rivets?

Ans. About 85 per cent of the original bar.

86. What is the shearing resistance of steel rivets?

Ans. 77 per cent of the original bar.

87. What is meant by efficiency of the joint?

Ans. The percentage of strength of the solid plate, that is retained in the joint.

88. What should be the style of joint with sheets thicker than $\frac{1}{2}$ inch?

Ans. It should be a double butt joint.

89. What should be the ratio of diameter of rivet to thickness of plate for double butt joints?

Ans. The diameter of the rivet should be about 1.8 times the thickness of sheet.

90. What should be the pitch of rivets?

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Ans. Three and one-half to four times the diameter of the hole.

91. Describe the triple riveted butt joint.

Ans. It has two welts or straps, one inside, and one outside.

92. Is this a good form of joint?

Ans. It is.

93. What type of joint gives the highest efficiency?

Ans. A joint in which the tensile strength of the rods from which the rivets are cut approaches that of the plates, and when the proportions of the joint are such, that the tensile strength of the rivets, and the crushing resistance of the rivets and plate, for a given, or unit strip, are as nearly equal as it is possible to make them.

94. In how many ways may failure occur in a double riveted butt joint?

Ans. In five distinct ways.

95. Name the first manner of failure.

Ans. Tearing of the plate at outer row of rivets.

96. What is the second?

Ans. Shearing two rivets in double shear, and one in single shear.

97. What is the third manner of failure?

Ans. Tearing of the plate at inner row of rivets, and shearing one rivet in the outer row.

98. Describe the fourth method of failure.

Ans. Crushing in front of three rivets.

99. What is the fifth manner of failure?

Ans. Crushing in front of two rivets, and shearing one.

100. How may a triple riveted butt joint fail?

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Ans. First: By tearing the plate at the outer row of rivets. Second: By shearing four rivets in double shear, and one in single shear. Third: Rupture of the plate at the middle row of rivets, and shearing one rivet. Fourth: Crushing in front of four rivets, and shearing one rivet.

101. What is the efficiency of the quadruple riveted butt joint?

Ans. In some cases as high as 94 per cent.

102. In what four ways may failure occur in this type of joint?

Ans. First: By tearing the plate at the outer row of rivets. Second: By shearing eight rivets in double shear, and three in single shear. Third: By tearing at inner row of rivets, and shearing three rivets. Fourth: By tearing at first outer row of rivets where the pitch is 7½ inches.

103. What is implied in the staying of a flat surface?

Ans. Holding it against pressure at a series of isolated points, which are arranged in symmetrical order.

104. Does the cylindrical shell of a boiler need bracing?

Ans. No.

105. Why is this?

Ans. Because the internal pressure tends to keep it cylindrical.

106. How are the heads sometimes stayed?

Ans. By through stay rods of soft steel, or iron 1¼ or 2 inches in diameter extending through from head to head.

107. What advantage has this form of stays?

Ans. The pull is at right angles to the plate.

108. What other methods of bracing the heads of high pressure boilers are used?

Ans. Gusset stays, and dished heads.

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109. What is the minimum factor of safety for stays, and braces?

Ans. Eight.

110. Give a simple rule for finding the bursting pressure of unstayed flat surfaces.

Ans. **Multiply the thickness of the plate in inches by ten times the tensile strength and divide the product by the area of the surface in square inches.**

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Boiler Setting and Equipment

111. What two methods of support are generally used in the setting of horizontal tubular boilers?

Ans. First: By suspension from I beams and girders, and secondly by means of brackets riveted to the side sheets, and resting upon the side walls.

112. How are water tube boilers usually supported in the setting?

Ans. By suspension.

113. What important details should be looked after concerning the brick work?

Ans. The foundations should be good, and the walls built in such manner as to take care of the expansion and contraction.

114. How is this accomplished?

Ans. By leaving an air space of two inches in the side and rear walls beginning at the level of the grate bars, and extending up to about the center line of the boiler.

115. What kind of brick should be used for inside lining?

Ans. Fire brick of good quality.

116. How should bridge walls be built for horizontal tubular boilers?

Ans. Straight across from wall to wall.

117. About what distance from the bottom of the boiler should this wall be?

Ans. Eight to ten inches.

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118. Where is the combustion chamber?

Ans. It is the space back of the bridge wall.

119. How should boiler walls be secured?

Ans. By means of tie rods extending the entire length, and breadth of the setting.

120. What are the buck stays?

Ans. They are strong cast-iron, or wrought-iron bars placed vertically upon the outside of the walls, and secured to the tie rods.

121. Should horizontal tubular boilers be set perfectly level lengthwise?

Ans. It is better that they be set about one inch lower at the back end, than at the front end.

122. Give one of the main reasons for this style of setting.

Ans. When washing out the boiler, the mud and water will more easily drain towards the blow off pipe.

123. What is the usual ratio of grate surface to heating surface?

Ans, One square foot of grate surface to each 36 square feet of heating surface.

124. At what point should the glass water-gauge be located?

Ans. In such a position as to bring the lowest visible portion of the gauge glass exactly on a level with the top of the upper row of tubes of a horizontal tubular boiler. With other types of boilers the lowest end of the gauge glass should always be on a level with the danger point.

125. Why should the above rules be observed in locating a water column?

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Ans. Because when the water level in the glass begins to draw near to the lower end of glass the engineer or water tender will have an infallible guide to warn him to get busy.

126. What is a good indication that the connections of the water glass are choked or plugged with scale?

Ans. When there is no movement of the water in the glass.

127. Why should there be a trap, or siphon in the pipe connecting the steam gauge to the boiler?

Ans. To prevent the hot steam from coming into contact with the spring of the gauge.

128. How may the steam gauge, and safety valve be tested in comparison with each other?

Ans. By occasionally raising the steam pressure high enough to cause the valve to open at the point for which it is set to blow.

129. Is the pop valve reliable as a safety valve?

Ans. It is, if not allowed to stand idle too long and become rusty,

130. How often should it be allowed to blow off?

Ans. At least twice a week.

131. Are lever safety valves used to any extent?

Ans. They are still in use to some extent, but are rapidly being superseded by pop valves.

132. What is the function of a fusible plug?

Ans. The fusible alloy of which it is composed will melt when it comes in contact with dry steam, and allow the steam to blow a warning.

133. Where is the fusible plug located?

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Ans. In that portion of the heating surface of a boiler which is first liable to be overheated from lack of water.

134. Are Domes and Mud drums necessary parts of boilers?

Ans. They are not as a rule.

135. Where should the blow off pipe always be connected?

Ans. With the lowest part of the water space.

136. Should the blow off cock be opened while the boiler is under pressure?

Ans. Yes, for a few seconds, once, or twice each day.

137. Is a surface blow off any advantage?

Ans. It is, especially if the water is muddy.

138. What precautions should be observed with regard to inlet for feed water?

Ans. The feed water should not be allowed to come directly in contact with the hot boiler sheets until its temperature is equal to, or near that of the water within the boiler.

139. How may this be brought about?

Ans. By means of feed water heaters, and internal coils of pipe through which the feed water is caused to pass.

140. What is the most economical style of feed pump?

Ans. The belt-driven power pump.

141. Is it the most reliable, or safest?

Ans. It is not.

142. What is the most reliable boiler feeding device, for all conditions of stationary practice?

Ans. The double acting steam pump.

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143. What precautions should be observed in figuring on the capacity of a feed pump for a battery of two or more boilers?

Ans. To take into account the total quantity of water required by all of the boilers; and let the capacity of the pump be equal to it.

144. In connection with feed apparatus for boilers, what other fittings and devices should be installed?

Ans. There should be a tee located in the horizontal section of the feed pipe near the check valve, and between it and the feed pump. One opening of this tee is to be reduced to ⅜ or ½ inch to receive a hot water thermometer for testing the temperature of the feed water when making evaporative tests, etc.

145. What other provisions along this line should be made?

Ans. Tanks for weighing the feed water—also a separate feed pipe to the boiler under test, also means for weighing the coal burned during test.

146. Is the injector an efficient boiler feeder?

Ans. It is in locations where there is not very much exhaust steam available for heating the feed water.

147. When, and by whom was the injector invented?

Ans. In the year 1858, by Henri Giffard.

148. Why does an injector force water into a boiler that is under steam pressure?

Ans. Because the steam passing through the injector imparts sufficient velocity to the water to overcome the boiler pressure.

149. Why does an injector lift water from a lower level?

Ans. Because the condensation of the steam in the combining tube creates a vacuum there, and in the suction pipe connected with it.

150. How may the size of the steam header for a battery of boilers be determined?

Ans. The sectional area of the header should equal or slightly exceed the sum of the areas of all the boiler outlets to be connected with it.

151. Where should all connections except for drainage, enter, and leave the main header?

Ans. At the top.

152. How many valves should there be in each boiler connection leading to the header?

Ans. Never less than two.

153. What kind of valves are best for this purpose?

Ans. Automatic stop, and check valves.

154. What is the most efficient type of superheater for practical purposes?

Ans. The one that is contained within the boiler setting.

155. How is the velocity of flow, or piston speed per minute of a pump ascertained?

Ans. Multiply number of strokes per minute by length of stroke in feet, or fractions thereof.

156. The piston speed being known, how is the velocity of flow in the discharge pipe found?

Ans. The velocity of flow in the discharge pipe is in inverse ratio to the squares of the diameters of the pipe and the water cylinder of pump.

157. When it is required to discharge a certain quantity of water from a given size of pipe in a given time, how may the velocity of flow in feet per minute be found?

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Ans. Multiply the number of cubic feet to be discharged by 144 and divide by area of pipe in inches.

158. When the volume of water to be discharged and the velocity of flow are known, how is the area of the pipe obtained?

Ans. Multiply volume in cubic feet by 144, and divide by velocity in feet per minute.

159. What is meant by "acceleration of gravity," and what constant number represents it in connection with hydraulics?

Ans. Acceleration of gravity is the increase in velocity caused by the actual weight of the water, and is represented by the constant 32.

160. What per cent of allowance is ordinarily made for friction in water pipes?

Ans. A deduction of 25 per cent is sufficient.

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Feed Water Heaters

161. Is a feed water heater an economical factor in the equipment of a boiler plant?

Ans. It certainly is, provided exhaust steam is used for heating.

162. How many kinds of exhaust heaters are there?

Ans. Two, viz.: Open, and closed.

163. Describe in brief terms the action of a so-called open heater.

Ans. The exhaust steam mingles directly with the water, and a portion of it is condensed.

164. Describe the operation of a closed heater.

Ans. The exhaust steam and the water are kept separate. In some cases the steam passes through tubes that are surrounded by water, and in other types the water fills the tubes that are surrounded by steam.

165. What difference exists between the two kinds of heater?

Ans. The closed heater is under full boiler pressure when the feed pump is working, while the open heater is not because the feed pump is between it and the boiler.

166. What per cent of saving in fuel may be effected by the use of a heater?

Ans. From 12 to 15 per cent.

167. Of what capacity should a feed water heater be, relative to the boilers?

Ans. It should have capacity sufficient to supply the boilers for 15 or 20 minutes.

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168. Can the exhaust injector be used for feeding boilers.

Ans. It can if the boiler pressure does not exceed 75 pounds.

169. What advantages are gained by the use of mechanical stokers?

Ans. Regulation of the supply of fuel to meet the demand for steam; also the opening and closing of furnace doors is avoided.

170. What are the disadvantages attending the use of mechanical stokers?

Ans. First, cost of installation. Second, in case of a sudden demand for steam the mechanical stoker cannot respond as quickly as in hand firing. Third, extra cost for power to operate them.

171. Into how many classes are mechanical stokers grouped?

Ans. Four.

172. Enumerate, and briefly describe.

Ans. Class one—An endless chain of short grate bars that travel horizontally over sprocket wheels.

Class two—Grate bars similar to the ordinary type having a continuous motion up and down, or forward and back, the bars being either horizontal or slightly inclined.

Class three—Grate bars steeply inclined and having a slow motion.

Class four—Under feed stoker in which the coal is pushed up onto the grate by means of a revolving screw, or steam ram.

173. In what three forms is mechanical draft used for boilers.

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Ans. First—Induced draft.

Second—Forced draft, in which fans force air beneath the grates.

Third—A combination of induced and forced draft.

174. Is a good draft necessary for the efficient operation of steam boilers?

Ans. It certainly is. The economical combustion of fuel cannot be accomplished without a good draft.

175. For what two purposes are chimneys required?

Ans. First, to carry off obnoxious gases. Second, to create sufficient draft for the combustion of the fuel.

176. What factor governs the intensity of the draft, independent of the dimensions of the chimney?

Ans. The difference in weight of the outside and inside columns of air.

177. What is the best shape of chimney?

Ans. Round, with a straight flue.

178. What is the weight, and volume of air at a temperature of 60°, and under average atmospheric pressure at sea level?

Ans. One cubic foot weighs 536 grains, and 13.06 cubic feet weigh one pound.

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Care and Operation of Boilers

179. What is one of the most important duties of the engineer when he goes on watch?

Ans. To ascertain the exact height of the water in his boilers.

180. Describe the correct method of doing this.

Ans. Open the valve in the drain pipe of the water column, and allow the water to blow out freely for a few seconds, then close the valve and note the level of the water when it settles back in the gauge glass.

181. What is the next important step in beginning the day's work?

Ans. To see that the fires are cleaned, and in good condition.

182. In firing boilers by hand, what is the first and most important rule to be observed?

Ans. Keep a clean fire.

183. What is the second rule?

Ans. See that every square inch of grate surface is covered with a good live fire.

184. Give the third rule regarding firing by hand.

Ans. Keep a level fire.

185. What is the fourth rule?

Ans. When cleaning the fire, always clean all clinkers and dead ashes away from the back end of the grates and the bridge wall.

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186. Why should this be done?

Ans. In order to allow a free passage of the air through the grate bars, so as to promote combustion.

187. If the plant runs continuously, day and night, what is one of the important duties of the fireman coming off watch?

Ans. To leave clean fires, clean ash pits, and a good supply of coal ready for the oncoming force.

188. How long a time should the fires be allowed to burn before cleaning?

Ans. This depends upon the quality of the coal. With a coal that does not clinker on the grate bars, an interval of 7 or 8 hours may elapse between cleanings, but with the average soft coal the fires should not be allowed to burn longer than 4 or 5 hours without cleaning.

189. What is one of the greatest aids to good combustion in a hand-fed furnace?

Ans. A clean bridge wall, kept as hot as possible

190. What precautions should be observed regarding the depth of the fire?

Ans. It should not be allowed to become so deep and heavy as to prevent the air from passing up through it freely.

191. How should the position of the ash-pit doors be regulated?

Ans. With a clean, light fire, a slight opening will be sufficient, but with a heavy fire, and the grates clogged with ashes, a larger opening is necessary.

192. How can the best results be secured in firing bituminous coal?

Ans. By leaving the fire doors slightly open for a few seconds immediately after throwing in a fire.

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193. What reason is there for doing this?

Ans. Because the volatile matter in the coal flashes into flame the instant it comes in contact with the heat of the furnace, and unless there is sufficient supply of oxygen present just then, the combustion will be imperfect.

194. What is the result of this imperfect combustion?

Ans. The formation of carbonic oxide gas, and the consequent loss of about two-thirds of the heat units contained in the coal.

195. How may this loss be prevented in a great measure?

Ans. By admitting a sufficient volume of air, either through the fire doors, directly after throwing in a fresh fire, or, better still, providing air ducts through the bridge wall, or side walls, which will direct the air in on top of the fire.

196. How much air is required for the complete combustion of one pound of coal?

Ans. By weight 12 pounds—by volume 150 cubic feet.

197. What precaution is necessary regarding the tubes of a boiler in order to get the best results from the fuel?

Ans. The tubes should be kept clean and free from soot and scale.

198. Should the steam jet cleaner be depended upon alone for cleaning the tubes?

Ans. No. The scraper should also be used.

199. How should safety valves be looked after?

Ans. They should be ample in size, never overloaded, and should be tested at least once a day to see that they act freely.

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200. At what point should the steam gauge pointer stand when the pressure is off?

Ans. It should stand at zero.

201. What should be done in case of low water in a boiler?

Ans. The fire should be covered immediately with ashes, earth, or if neither is available use fresh coal. Draw the fire as soon as it can be done without increasing the heat.

202. Should the rate of feeding the water be increased, in case of extremely low water in the boiler?

Ans. It should not, neither should the engine be stopped or the safety valve lifted, until the fires are out, and the boiler cooled down.

203. In case of indications of cracks or blisters appearing on the boiler sheets, what should be done?

Ans. There should be no delay in making repairs.

204. What should be done with fusible plugs when used?

Ans. They should be cleaned and carefully scraped on both water and fire sides at each washing out.

205. How may the most economical results regarding fuel be attained with a steam boiler?

Ans. By keeping the heating surfaces clean, both inside and outside, also careful firing, a little at a time, but keeping the grates covered.

206. Should cold water ever be fed into a boiler when it is under pressure?

Ans. Not when it can be avoided.

207. How may foaming usually be stopped?

Ans. By checking the outflow of steam, by blowing down and pumping up, or by checking the draft and fires.

208. Should air be allowed to pass to the boiler or tubes, except through the furnace?

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Ans. It should not, as it will cause a waste of fuel.

209. What should be done with leaks when discovered?

Ans. They should be repaired as soon as possible.

210. What precautions should be observed when preparing to empty a boiler for washing out, or other purposes?

Ans. Allow it to cool down until there is no steam pressure, and until the brick work is cool also.

211. When firing up a boiler what course should be pursued?

Ans. Steam should be raised very slowly, and rapid firing avoided.

212. What bad results follow too rapid firing up of a boiler?

Ans. Straining of the joints and seams caused by unequal expansion.

213. What should be done with a boiler that is to stand idle for any length of time?

Ans. It should be emptied, and thoroughly dried. In case this is impracticable, fill it full of water, and put in a quantity of washing soda.

214. How long a time may a boiler be safely operated between dates of washing out?

Ans. This depends upon the nature of the feed water. The time should never be longer than two weeks, and with very bad water, the boiler should be washed out once a week.

215. Besides cleaning the boiler inside, what other very important work should the boiler washer perform while inside the boiler?

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Ans. He should closely examine all braces, stays, and rivets by tapping them with a hammer. Any loose or defective parts can usually be detected in this way.

216. Describe four ways in which tube failures may occur.

Ans. 1. Pitting. 2. Defective welds. 3. Bagging. 4. Scabbing and blistering.

217. How may a great saving in fuel be effected with regard to the feed water?

Ans. By heating it with the exhaust steam from engines and pumps before passing it to the boilers.

218. Describe the available heating surface of a stationary boiler, of either type, return tubular or water tube.

Ans. The lower half of the shell, and heads, and the combined cross sectional area of all the tubes.

219. What should be the location of the water gauge glass, relative to the water level in the boiler?

Ans. It should be located at such a height as to bring the lower end of the glass tube on a level with the danger point for low water in the boiler.

220. Where should the lower gauge cock be located relative to the danger point?

Ans. About three inches above.

222. Should an engineer or water tender depend entirely upon the water gauge glasses?

Ans. He should not, but should frequently open and try the gauge cocks.

223. What should be done with the entire water column several times a day?

Ans. It should be blown out thoroughly.

224. What should be done with the safety valves in order to make them reliable?

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Ans. They should be allowed to blow off at least twice a week.

225. Why is this necessary?

Ans. Because the valves are liable to become corroded, and stick to their seats if not attended to properly.

226. What is the rule for finding the bursting pressure of boilers?

Ans. Multiply the tensile strength by the thickness and divide by one-half the diameter of the shell.

227. How may the safe working pressure of a boiler be ascertained?

Ans. By dividing the bursting pressure by five.

228. What is the rule for ascertaining the velocity of flow in a pump?

Ans. Multiply the number of strokes per minute by length of stroke in feet. This will give piston speed.

229. How may velocity of flow in the discharge pipe of a pump be found?

Ans. Divide square of diameter of water piston by the square of the diameter of pipe, and multiply by piston speed per minute.

230. What is the rule for finding velocity in feet per minute required to discharge a given quantity of water in a given time?

Ans. Multiply number of cubic feet to be discharged by 144 and divide by area of pipe in inches.

231. When the volume and velocity of water to be discharged are known, how may the area of the pipe be ascertained?

Ans. Multiply volume in cubic feet by 144 and divide by velocity in feet per minute.

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232. What is one of the main requisites in the successful burning of coal in a boiler furnace?

Ans. A good draft.

233. What is a common cause of lost economy in the operation of boilers?

Ans. Air leaks in the brick settings.

234. Mention another source of loss in connection with mechanical stokers.

Ans. The dead area of grate that is covered with a thin layer of clinker, and ash.

235. What is meant by the expression "priming?"

Ans. Carrying over into the cylinder of water in the form of fine spray mingled with the steam.

236. How may this be prevented to a large extent?

Ans. By placing a baffle plate in the steam space of the boiler, directly under the dome. Steam separators may also be employed for this purpose.

237. What should be the principal object in view in burning coal under a boiler?

Ans. To transfer as many as possible of the total heat units in the coal, to the water in the boiler.

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Combustion, Heat

238. What is meant by the term combustion as used in steam engineering?

Ans. It is the rapid chemical combination of oxygen with the carbon, hydrogen and sulphur in the fuel with the accompaniment of heat and light.

239. What is meant by the symbol CO_2?

Ans. CO_2 represents perfect combustion, viz., the creation of carbon dioxide.

240. What is the most abundant combustible in nature?

Ans. Carbon.

241. How many heat units are contained in one pound of pure carbon?

Ans. 14,500.

242. What is the heating value of one pound of hydrogen gas?

Ans. 62,000.

243. Give the composition of coal.

Ans. Fixed carbon, volatile matter, ash and sulphur in various proportions, depending upon the quality of the coal.

244. Is sulphur desirable as a constituent of coal?

Ans. It is not. The gases formed from its combustion attack the metal of the boiler, causing corrosion.

245. What office does nitrogen perform in combustion?

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Ans. No useful office. Rather it is a detriment, and in fact is the chief source of loss in furnaces. It is drawn in with the air.

246. What is meant by the term calorific value of fuel?

Ans. The amount of heat liberated per pound of fuel undergoing perfect combustion.

248. What are economizers in connection with a boiler plant?

Ans. Coils or stacks of cast iron pipe placed within the smoke flue, or breeching and surrounded by the hot gases while the water is passed through the pipes on its way to the boilers, thus receiving an additional amount of heat.

249. What two factors are necessary in order to attain economy in the burning of coal?

Ans. A constant high furnace temperature and quick combustion.

250. Define the term heat.

Ans. Heat is the result of the vibration of the molecules or atoms composing matter.

251. Upon what does the intensity of heat depend?

Ans. Upon the rapidity of the agitation to which the molecules are subject.

252. What are the general effects of heat?

Ans. When heat is added to, or taken away from a body the temperature of the body is altered and its volume is varied.

253. What is absolute zero?

Ans. It is that degree of temperature at which, owing to the intense cold, a perfect gas would disappear. Absolute zero is 461° below the zero of the Fahrenheit thermometer.

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254. What is a heat unit (B. T. U.)?

Ans. It is the quantity of heat required to raise the temperature of one pound of water one degree, or from 39° to 40° F.

255. What is the mechanical equivalent of heat?

Ans. 778 foot pounds; in other words, 778 pounds raised one foot high.

256. What is the specific heat of any substance?

Ans. The ratio of the quantity of heat required to raise a given weight of that substance one degree in temperature, to the quantity of heat required to raise an equal weight of water one degree when the water is at its maximum density, viz., 39.1° F.

257. What is latent heat?

Ans. Heat given to a body and not warming it.

258. What is sensible heat?

Ans. Heat given to a body and warming it.

259. Of what is pure water composed?

Ans. By volume—Hydrogen 2 parts, oxygen 1.
By weight—Hydrogen 11.1 parts, oxygen 88.9.

260. Is perfectly pure water desirable for use in a steam boiler?

Ans. It is not, as it will cause corrosion and pitting of the sheets.

261. What two ingredients in water are the chief causes of incrustation in boilers?

Ans. The carbonates of lime and magnesia.

262. What is steam?

Ans. Steam is the vapor of water generated by an increase of the natural vibrations of molecules of the water through the application of heat.

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263. What is saturated steam?

Ans. Steam taken directly from the boiler to the engine without being superheated.

264. What is superheated steam?

Ans. Steam that has been heated to a higher temperature than that due to its pressure.

265. What should be done with all pipes through which live steam is conducted for purposes of heating, or power?

Ans. They should be well protected by a covering, in order to prevent loss of heat by radiation.

266. In what respect should steam be considered in its relation to the engine?

Ans. As a vehicle for transferring the heat energy from the boiler to the engine.

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Evaporation Tests

267. What is the primary object of an evaporation test?

Ans. To ascertain how many pounds of water the boilers are evaporating per pound of coal burned.

268. What other important points relative to boiler operation may be determined by these tests?

Ans. There are four. First—To determine the efficiency of the plant as an apparatus for the consumption of fuel, and the evaporation of water. Second—To determine the relative economy of different varieties of coal, and other fuels. Third—To determine whether or not the boilers are being operated as economically as they might be. Fourth—To determine whether the boilers are being over worked.

269. In what condition should the testing apparatus be maintained?

Ans. In first-class condition, ready to be used at any time for making a test.

270. What should be done with the boiler, and all of its appurtenances preparatory to making a test?

Ans. They should be put in good condition, by cleaning, etc.

271. How should the boiler under test be operated during the test?

Ans. At its full capacity.

272. Where should the water level be at the beginning, and close of the test?

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Ans. At the height ordinarily carried, and its position should be marked by tying a cord around one of the guard rods of the gauge glass.

273. How long should the test last?

Ans. About 10 hours.

274. How is the percentage of moisture in the steam determined?

Ans. By means of the calorimeter.

275. How many, and what kind of calorimeters are used for this purpose?

Ans. Two. The throttling calorimeter, and separating calorimeter.

276. Upon what principle does the throttling calorimeter act?

Ans. Upon the principle of temperatures.

277. How does the separating calorimeter act?

Ans. It mechanically separates the water from a known volume of steam passing through it.

278. In what other manner may the condition of steam regarding its dryness be approximated?

Ans. By observing its appearance as it issues from a pet cock, or other small opening.

279. How will steam containing 1 or 2 per cent of moisture appear under such conditions?

Ans. It will be transparent close to the orifice from which it issues.

280. How is the chimney draft measured?

Ans. By means of a draft gauge.

281. What is the usual form of draft gauge?

Ans. A glass tube bent in the shape of the letter U.

282. Describe the action of a draft gauge.

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Ans. One leg of the U tube is connected to the chimney by a small rubber hose. The other leg is open to the atmosphere. The tube is partly filled with water, which when there is no draft will stand at the same height in both legs.

283. When there is a draft and the rubber hose is connected to the chimney how is the water in the U tube affected?

Ans. The draft suction causes the water in the leg to which the hose is connected, to rise while the level of the water in the other leg will be equally depressed.

284. How is the intensity of the draft thus estimated?

Ans. In fractions of an inch, .5, .7 or .75 inches.

285. What is the object of flue gas analysis?

Ans. There are three. First—To determine the amount of excess air admitted to the furnace. Second—To determine the character of the combustion. Third—To ascertain the heat losses.

286. What weight of oxygen is required for the complete combustion of one pound of carbon?

Ans. 2.67 pounds. By volume, 32 cubic feet.

287. What gaseous combination is produced by complete combustion?

Ans. Carbon dioxide (CO_2).

288. What is the result of imperfect combustion?

Ans. Carbon monoxide (CO).

289. How is the efficiency of the boiler and furnace ascertained through an evaporation test?

Ans. By weighing the coal consumed and the water evaporated during a certain number of hours and dividing the number of pounds of water evaporated by the number of pounds of coal consumed. This will give number of pounds water evaporated per pound of coal.

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290. What is meant by the term "equivalent evaporation?"

Ans. It assumes that the feed water enters the boiler at a temperature of 212°, and is evaporated into steam at 212° and at atmospheric pressure.

291. Why is this standard necessary in evaporation tests?

Ans. Because of the variations in the temperature of the feed water used in different tests.

292. What is meant by boiler horse-power?

Ans. The evaporation of 34½ pounds water from a feed temperature of 212° into steam of the same temperature; or the evaporation of 30 pounds water from a feed temperature of 100° into steam at 70 pounds gauge pressure.

293. What is meant by the expression "total heat of evaporation?"

Ans. The sum of the sensible heat plus the latent heat, at boiling point.

294. What is steam in its relation to the engine?

Ans. It is merely a vehicle for transferring the heat energy from the boiler to the engine shaft.

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Steam Engines

295. Into what two general classes are steam engines divided.

Ans. Simple and compound.

296. Describe a simple engine.

Ans. A simple engine may be either condensing or non-condensing, but its leading characteristic is, that the steam is used in but one cylinder.

297. What is a condensing engine?

Ans. One in which the exhaust steam is passed into an air-tight vessel in which a vacuum is maintained, the exhaust steam being there condensed by coming in contact with cold water, or a series of tubes through which cold water is being circulated.

298. Describe a compound engine?

Ans. A compound engine is one in which the steam is made to do work in two or more cylinders before it is allowed to exhaust.

299. How is this accomplished?

Ans. By causing the exhaust steam from the first, or high pressure cylinder, to pass into a second cylinder of larger diameter, and, if the engine be triple or quadruple expansion, from thence into a third or fourth cylinder, the diameters of which increase in regular ratio.

300. What is a non-condensing engine?

Ans. One from which the steam exhausts directly into the atmosphere, or is used for heating purposes before passing out into the open air.

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301. What disadvantage does a non-condensing engine constantly labor under?

Ans. The pressure of the atmosphere amounting to 14.7 pounds per square inch is constantly in resistance to the motion of the piston.

302. Mention several other causes that tend to increase the back pressure upon the piston of a non-condensing engine.

Ans. The resistance of bends and turns in the exhaust pipe, also causing the exhaust to pass through feed water heaters or heating coils.

304. What is back pressure?

Ans. Pressure that tends to retard the forward stroke of the piston.

305. What advantage has a condensing engine over a non-condensing engine?

Ans. The atmospheric pressure is removed from in front of the piston to a degree corresponding to the height of the vacuum that is maintained in the condenser.

306. How many classes of condensers are there in general use?

Ans. Two; jet condensers and surface condensers.

307. Describe a jet condenser.

Ans. One in which the steam is exhausted into an air-tight vessel, and is there condensed by coming in contact with a jet or spray of cold water.

308. How is this water removed?

Ans. By means of the air pump, which also maintains a vacuum in the condenser.

309. Describe a surface condenser.

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Ans. It is an air-tight vessel, either cylindrical or rectangular in shape, fitted with a large number of brass or copper tubes, of small diameter, through which the cold water is forced by the circulating pump. A vacuum is maintained in the body of the condenser by the air pump, and the steam exhausted into this is condensed by coming in contact with the cool surface of the tubes. In some cases the steam passes through the tubes in place of around them, the condensing water being forced into and through the body of the condenser, and the vacuum being maintained in the tubes.

310. Describe an injector condenser.

Ans. A condenser in which the cold water is forced through an annular enlargement of the exhaust pipe, and passing down into a nozzle which gradually contracts. The exhaust steam entering at the same time is condensed, the water rushing through the nozzle with a velocity sufficient to create a vacuum.

311. About what quantity of water is required per horse-power per hour to condense the exhaust steam from an engine?

Ans. About 38 to 40 gallons, depending upon the temperature of the condensing water.

312. What three factors are necessary to insure good economy with multiple cylinder engines?

Ans. First—A high initial pressure. Second—Expansion of the steam to greatest extent possible. Third—Protecting the surfaces of the cylinders from cooling influences.

313. Describe a cross compound engine.

Ans. An engine consisting of two cylinders, each having its own connecting rod and crank, the cranks being set at opopsite ends of the engine shaft, and at an angle

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of 90° to each other. The high pressure cylinder exhausts into the low pressure cylinder, usually through a receiver.

314. Describe a tandem compound engine.

Ans. An engine having the two cylinders arranged tandem to each other, with a common piston rod, and connecting rod.

315. What advantage is gained by this design?

Ans. A much shorter and more direct route for the exhaust steam in its passage from the high to the low pressure cylinder.

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Valves and Valve Setting

316. What inportant features in the operation of an engine are dependent upon a correct adjustment of the valves?

Ans. The efficiency of the engine, the economical use of steam, and the regular and quiet action of the engine.

317. How many different types of valves are there in general use?

Ans. Slide, poppet, rotative, piston, gridiron, etc.

318. What are the basic principles governing the adjustment of the valves of an engine, regardless of the type?

Ans. Admission, cut-off, release, and exhaust closure; each of these functions to occur at the proper moment during one stroke of the piston.

319. Name two important functions of a valve.

Ans. Lap and lead.

320. What is the effect of increasing outside lap?

Ans. Later admission, and an earlier cut off.

321. What results from increasing inside lap?

Ans. Earlier exhaust closure, and an increased conpression.

322. What advantage has an engine of the four valve type over a single valve engine?

Ans. Each individual valve may be adjusted inpendently of the others.

323. If a valve had neither lap nor lead what would be the position of the eccentric relative to the crank?

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Ans. 90° ahead of the crank.

324. What is meant by the term "angular advance," and why is it necessary?

Ans. The distance that the high point of the eccentric is set ahead of a line at right angles with the crank. It is necessary in order to give the valve lap, and lead.

325. What is the first function of the valve at the commencement of the stroke?

Ans. Lead, or admission.

326. What is the second function?

Ans. Full port opening.

327. What is the travel of a valve equal to?

Ans. Twice the port opening plus twice the outside lap.

328. What is the third function of the valve?

Ans. Cut off.

329. What is the fourth function?

Ans. Exhaust closure, or compression.

330. What will be the effect if the valve has no inside lap?

Ans. An early release, and no compression.

331. What is meant by "radius of eccentricity?"

Ans. One half the travel of the valve.

332. What is an eccentric?

Ans. A mechanical device for converting rotary into reciprocating motion. Its center of revolution is apart from its center of formation.

333. What is the "throw" of an eccentric?

Ans. The distance from the center of the eccentric to the center of the shaft.

334. What is meant by eccentric position?

Google

Ans. The location of the highest point of the eccentric relative to the center of the crank pin, expressed in degrees.

335. What is valve travel?

Ans. The distance covered by the valve in its movement.

336. What is lap?

Ans. The amount that the ends of the valve project over the edges of the ports when the valve is at mid travel.

337. What is inside lap?

Ans. The lap of the inside, or exhaust edge of the valve over the inside edge of the port.

338. What is outside lap?

Ans. The lap of the outside edge of the valve over the outside edge of the port.

339. What is lead?

Ans. The amount that the port is open when the crank is on the dead center.

340. Why must a valve have outside lap?

Ans. Because admission and cut off are controlled thereby.

341. Why should a valve have inside lap?

Ans. In order that release and compression may be properly controlled.

342. What is the effect of decreasing the angular advance?

Ans. All the important functions of the valve occur later.

343. What results follow from decreasing the travel of the valve?

Ans. Less lead, a later admission and release, and an earlier cut off and compression.

344. What is meant by automatic or variable cut off?

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Ans. A system in which full boiler pressure is constantly maintained in the valve chest, the speed being regulated by the governor controlling the point of cut off.

345. What is meant by fixed cut off?

Ans. When the point of cut off remains the same, regardless of the load, the speed being regulated by throttling the steam.

346. What three changes must be made in order to cause an earlier cut off on an engine that has a fixed cut off?

Ans. First—Increase the angular advance. Second—Increase the outside lap. Third—Increase the inside lap.

347. What is the first step in valve setting?

Ans. To place the engine on the dead center.

348. What is meant by the dead center?

Ans. When the piston is at the end of the stroke, and the centers of the crank shaft, crank pin, and cross head pin are in line.

349. What rule should be observed in turning an engine to place it on the dead center?

Ans. Always turn it in the direction in which it is to run.

350. Why is this necessary?

Ans. In order to guard against errors which might result from lost motion in the parts.

351. Having placed the engine on the dead center, what is to be done next?

Ans. Adjust the eccentric rod to the proper length?

352. What should be done with the valve before connecting it with the eccentric rod?

Ans. It should be placed at mid travel, and marked.

353. What is necessary before the valve can be placed in its central position?

Ans. The exact amount of outside lap must be known.

354. What amount of lead is usually given to the valve?

Ans. From $\frac{1}{32}$ in. to $\frac{1}{8}$ in. depending upon the size of the engine.

355. What is the function of the governor?

Ans. To properly regulate the speed of the engine.

356. Explain the action of a governor?

Ans. Its action is based upon the principle of the centrifugal, and centripetal forces, which cause the balls or weights attached to the arms, to fly outward or inward as their speed of revolution increases or decreases.

357. In what manner is this movement of the balls caused to regulate the speed?

Ans. In the pendulum or fly ball governor, the motion is transferred by means of levers and rods to the cut off mechanism. In the shaft governor the changes in the position of the weights change the angular advance of the eccentric, thus causing an earlier or later cut off, according as the load is light, or heavy.

358. In what way does the throttling governor regulate the speed of an engine?

Ans. It controls the position of a valve in the steam pipe, opening or closing it according as the engine needs more, or less steam to maintain a regular speed.

359. What is compression?

Ans. If the exhaust port is closed by the valve, just before the piston reaches the end of stroke, a portion of the steam will be entrapped in the cylinder, and being ahead of the piston will be compressed.

360. Is there any advantage in this?

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Ans. Yes. The steam thus compressed acts as a cushion for the piston, preventing shock or jar to the moving parts on reaching the end of the stroke.

361. What is an adjustable cut off?

Ans. One in which the point of cut off may be adjusted by a hand wheel attached to the valve stem of a throttling governor.

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Definitions

362. What is absolute pressure?

Ans. Pressure reckoned from a perfect vacuum.

363. What is gauge pressure?

Ans. Pressure above atmospheric pressure.

364. What is initial pressure?

Ans. Pressure in the cylinder at the beginning of the stroke.

365. What is terminal pressure?

Ans. Pressure in the cylinder at the end of the stroke.

366. What is mean effective pressure (M. E. P.)?

Ans. The average pressure acting upon the piston throughout the stroke.

367. What is back pressure?

Ans. Pressure tending to retard the forward stroke of the piston.

368. What is absolute back pressure?

Ans. Back pressure measured from a perfect vacuum.

369. What is the ratio of expansion?

Ans. The relative volume of steam in the cylinder at point of release, compared to volume at cut off.

370. What is wire drawing of steam?

Ans. Restricted passage of the steam caused by too small a steam pipe.

371. What is condenser pressure?

Ans. Pressure existing in the condenser caused by the lack of vacuum.

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372. What is vacuum?

Ans. That condition existing within a closed vessel from which all matter, including air has been expelled.

373. What is absolute zero?

Ans. 461.2° below zero Fahr.

374. What is piston displacement?

Ans. The space swept through by the piston in a single stroke.

375. What is piston clearance?

Ans. The distance between the piston and cylinder head at the end of the stroke.

376. What is steam clearance?

Ans. The distance between the piston at end of stroke, and the valve face.

377. What is a horse power (H. P.)?

Ans. 33,000 lbs. raised one foot in one minute of time.

378. What is indicated horse power (I. H. P.)?

Ans. The horse power as shown by the indicator diagram.

379. What is piston speed?

Ans. The distance in feet traveled by the piston in one minute.

380. Give the rule for figuring the horse power?

Ans. Area of piston in square inches $\times$ M. E. P. $\times$ piston speed $\div$ 33,000.

381. What is net horse power?

Ans. I. H. P. minus engine friction.

382. Define Boyle's law of expanding gases?

Ans. Pressure at constant temperature varies inversely as the space it occupies.

383. What is an adiabatic curve?

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Ans. The curve of expanding gas that loses no heat while expanding.

384. What is an isothermal curve?

Ans. The curve of an expanding gas of constant temperature, but influenced by moisture.

385. What is an expansion curve?

Ans. The curve traced upon the diagram by the indicator pencil.

386. Define the first law of thermodynamics.

Ans. Heat and mechanical energy are mutually convertible.

387. What is power?

Ans. The rate of doing work.

388. What is the unit of work?

Ans. The foot pound, viz., the raising of one pound, one foot high.

389. Define the first law of motion?

Ans. All bodies continue either in a state of rest, or of uniform motion in a straight line, unless compelled by impressed forces to change that state.

390. What is work, mechanically considered?

Ans. Pressure$\times$distance passed through$\times$time.

391. What is momentum?

Ans. Mass$\times$density.

392. What is dynamics?

Ans. The science of moving powers.

393. What is force?

Ans. That which alters the motion of a body, or puts in motion a body that was at rest.

394. Define the maximum theoretical duty of steam?

Ans. Mechanical equivalent of heat$\times$total heat units in a pound of steam?

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395. How may steam efficiency be expressed?

Ans. Heat converted into useful work÷heat expended.

396. How may engine efficiency be expressed?

Ans. Heat converted into useful work÷total heat received in the steam.

397. How may efficiency of the plant be expressed?

Ans. Heat converted into useful work÷calorific or heat value of the fuel.

398. What is horse power constant?

Ans. The power the engine would develop with one pound M. E. P.

399. What is meant by steam consumption per H. P. per hour?

Ans. Weight in pounds of steam used÷H. P. developed.

400. What are ordinates as applied to indicator diagrams?

Ans. Parallel lines drawn at equal distances across the face of the diagram, perpendicular to atmospheric line.

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Indicator

401. What two important points are gained by the use of the indicator?

Ans. First—It shows the average pressure upon the piston throughout the stroke. Second—It shows the action of the valve or valves in admission, cut off and release of the steam.

402. What is the first principle of the indicator?

Ans. Pressure of the steam in the engine cylinder during an entire revolution, against a small piston in the cylinder of the indicator.

403. What resistance is in front of the indicator piston?

Ans. A spiral spring of known tension.

404. What is the second principle of the indicator?

Ans. By means of a multiplying mechanism of levers, the stroke of the indicator piston is communicated to a pencil moving in a straight line.

405. What is the third principle of the indicator?

Ans. By means of a reducing mechanism and cord, the motion of the engine piston during an entire revolution is imparted to a small rotating drum, to which is attached a piece of blank paper.

406. How is a diagram obtained?

Ans. The pencil is held against the paper and thus traces a diagram of the action of the steam within the engine cylinder.

407. What is the atmospheric line?

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Ans. A line drawn by the indicator pencil before communication is established between engine cylinder and indicator cylinder.

408. Where should a diagram from a non-condensing engine appear relative to the atmospheric line?

Ans. It should appear above the atmospheric line.

409. Where should the diagram from a condensing engine appear?

Ans. Partly above, and partly below the atmospheric line.

410. What is the best reducing motion to use?

Ans. The reducing wheel.

411. How is the indicator attached to the engine cylinder?

Ans. By means of half-inch pipe tapped into the side of the cylinder near the ends.

412. How are the springs numbered?

Ans. They are made for various pressures, and numbered accordingly.

413. What is a good rule to follow in selecting a spring?

Ans. Select one numbered one-half as high as the boiler pressure, which will give a diagram about two inches high.

414. What data should be noted upon the diagrams when they are taken?

Ans. Boiler pressure; time when taken, and which end of cylinder, head, or crank.

415. What pressure must always be deducted from the mean forward pressure (M. F. P.) in calculations for power?

Ans. The back pressure.

416. What bad effects follow unequal cut off?

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Ans. The engine will not develop the power that it is capable of—uneven strains will be set up.

417. What is a convenient size for a diagram?

Ans. 1½ or 2 inches high, and 2 or 2½ inches long.

418. What precaution regarding the pipe connections of the indicator should always be observed before taking diagrams?

Ans. They should be thoroughly blown out, and cleaned of all dirt.

419. How is the ratio of expansion found?

Ans. Divide absolute initial pressure by absolute terminal pressure.

420. Name a very important factor in the calculation of steam consumption of an engine.

Ans. The clearance space.

421. What is one of the first requisites in power calculations?

Ans. To ascertain the M. E. P.

422. How is this done?

Ans. In several ways, for instance by means of ordinates, or it may be obtained by the use of the Planimeter.

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Lubrication

423. What is one of the most important problems connected with engine operation?

Ans. The proper lubrication of the bearings.

424. What is friction?

Ans. The resistance caused by the motion of a body in contact with another body that does not partake of its motion.

425. What is the first law of friction?

Ans. Friction varies in proportion to the pressure on the surfaces in contact.

426. Define the second law of friction.

Ans. Friction is independent of the areas of surface in contact.

427. What is the third law of friction?

Ans. Friction increases with the roughness of the surfaces, and decreases as the surfaces become smoother.

428. What is the fourth law of friction?

Ans. Friction is greatest at the beginning of motion.

429. Give the fifth law of friction?

Ans. Friction is greater between soft bodies than it is between hard bodies.

430. When, and by whom were these laws first formulated?

Ans. In 1831-33 by Gen. Arthur Morin, a French engineer.

431. What is the tendency of friction with machinery in operation?

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Ans. It tends to cause the parts to adhere to each other.

432. How may this friction be largely obviated?

Ans. By proper lubrication of the rubbing surfaces.

433. Does friction serve any good purpose?

Ans. Yes, for instance the friction of the belt in contact with the rim of the pulley, also the friction of the driving wheels of a locomotive.

434. How many kinds of friction are there in connection with machinery in operation?

Ans. Two, viz., the friction of solids, and the friction of liquids.

435. What is meant by the term co-efficient of friction?

Ans. The ratio of the power required to move a body, and the pressure on that body.

436. What should be the object sought in the design of engine bearings?

Ans. To obtain as large a rubbing surface as possible.

437. Mention some of the qualities that a good lubricating oil should possess.

Ans. It should have a good "body"—must not dry or "gum;" must not be easily thinned by heat, or thickened by cold. Must be free from all gritty substances.

438. What is the proper kind of oil to use on a bearing that has started to heat?

Ans. Cylinder oil, owing to its high fire test.

439. Is graphite, or plumbago a good lubricant?

Ans. It is in many cases.

440. What is the essential function of graphite?

Ans. It is an auxiliary, or accessory lubricant.

441. Mention some of the points that govern interior lubrication of engine parts.

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Ans. The conditions of the surfaces; the steam pressure; the amount of moisture in the steam; piston speed; weight, and fit of moving parts, etc.

442. What properties should a good cylinder oil possess?

Ans. It must be of high flash test; must have good viscosity, or body when in contact with hot surfaces.

443. Upon what does the successful lubrication of an engine largely depend?

Ans. Upon the character of the lubricating appliances used.

444. What system of lubrication for cylinders, and valves is most largely used?

Ans. The hydrostatic, or sight-feed type of lubricator.

445. What other system has come into extensive use in late years?

Ans. The force feed, or mechanically operated oil pump.

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The Steam Turbine

446. Explain the chief points of difference between the action of the reciprocating steam engine, and the steam turbine.

Ans. The piston of the reciprocating engine is driven back and forth by the static expansive force of the steam; while in the steam turbine, not only is this static expansive force made to do work, but the velocity of the steam in expanding from a high, to a low pressure is also utilized in turning the rotor of the turbine.

447. What other important factors enter into the operation of a steam turbine?

Ans. The principles of reaction and impulse.

448. Name several of the more important advantages that the turbine has over the reciprocating engine.

Ans. First, highly superheated steam of a high initial pressure may be used in the turbine. Second, a larger proportion of the heat in the steam may be converted into work with the turbine. Third, there is much less friction with the turbine.

449. What is the most economical method of disposing of the exhaust steam from a turbine?

Ans. By allowing it to pass into a condenser.

450. Will the turbine expand the steam to as low a pressure as the reciprocating engine will?

Ans. Yes, and even lower.

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451. What type of condensing apparatus is necessary with the steam turbine.

Ans. The same kind that is used on reciprocating engines.

452. How low will a well regulated turbine allow the steam to expand?

Ans. To within one inch of the vacuum existing in the condenser.

453. What is the theoretical velocity of steam under 100 lbs. pressure if allowed to discharge into a vacuum of 28 inches?

Ans. 3860 feet per second.

454. How many ft. lbs. of energy would one cubic ft. of steam thus exert?

Ans. 59,900 ft. lbs.

455. What is the ratio of bucket speed to jet speed for impulse wheels.

Ans. Bucket speed equals one-half of jet speed.

456. What should be the ratio between bucket speed and jet speed, for reaction wheels.

Ans. 1 to 1. That is, the two speeds should be equal.

457. What should be the form or curvature of the blades, or buckets?

Ans. They should be of such form as will permit expansion of the steam with the least amount of friction, or eddy currents.

458. How are the stuffing boxes of steam turbines usually kept cooled?

Ans. By means of water applied in various ways.

459. How is the speed of steam turbines usually regulated?

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Ans. By simple throttling.

460. What are the ideal conditions under which a turbine should work?

Ans. A full initial pressure, and all cross sections of steam passages to be suitable to the power required.

461. Of what type is the Westinghouse-Parsons turbine?

Ans. It is both an impulse and reaction turbine.

462. How are the clearances between the blades preserved in this turbine?

Ans. By means of balancing pistons on the shaft.

463. What is the usual velocity of the steam in the Westinghouse-Parsons turbine?

Ans. 600 ft. per second.

464. How does the efficiency of steam turbines compare with that of reciprocating engines?

Ans. It is generally higher.

465. How is the heat energy in the steam imparted to the wheels of the Curtis turbine?

Ans. Both by impulse and reaction.

466. Describe the method of admission in the Curtis turbine.

Ans. The steam is admitted through expanding nozzles in which nearly all of the expansive force of the steam is transformed into the force of velocity. The steam is caused to pass through one, two, or more stages of moving elements, each stage having its own set of expanding nozzles, each succeeding set of nozzles being greater in number and of larger area than the preceding set.

467. What is the ratio of expansion in these nozzles?

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Ans. The ratio of expansion within these nozzles depends upon the number of stages, as, for instance, in a two-stage machine, the steam enters the initial set of nozzles at boiler pressure, say 180 lbs. It leaves these nozzles and enters the first set of moving blades at a pressure of about 15 lbs.

468. In a four-stage machine, with 180 lbs initial pressure, what would be the pressures at the different stages?

Ans. First stage, 50 lbs.; second stage, 5 lbs.; third stage, partial vacuum, and fourth stage, condenser vacuum.

469. How are the revolving parts of the Curtis turbine supported?

Ans. Upon a vertical shaft, which in turn is supported by, and runs upon a step bearing at the bottom.

470. How is this step bearing lubricated?

Ans. Oil is forced under pressure by a steam or electrically driven pump, the oil passing up from beneath.

471. How is the speed of the Curtis turbine regulated?

Ans. By varying the number of nozzles in flow.

472. How are the clearances adjusted in the Curtis turbine?

Ans. By means of the large step screw at the bottom.

473. How is the shaft packed to prevent steam leakage?

Ans. With carbon blocks made into rings fitting the shaft.

474. What type of turbine is the De Laval?

Ans. It is purely an impulse wheel.

475. What is the speed of the wheel?

Ans. From 10,000 to 30,000 revolutions per minute.

476. How is the heat energy in the steam utilized in the De Laval turbine?

Ans. In the production of velocity.

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477. What is the velocity of the steam as it issues from the expanding nozzles and impinges against the buckets?

Ans. About 4,000 ft. per second.

478. What is the usual peripheral speed of the wheel?

Ans. 1,200 to 1,300 feet per second.

479. Of what type is the Allis-Chalmers steam turbine?

Ans. It is essentially of the Parsons type.

480. How are the clearances between the revolving and stationary blades preserved?

Ans. By a thrust bearing.

481. What kind of bearings has the Allis-Chalmers turbine?

Ans. Self-adjusting ball and socket bearings.

482. What is the first move in preparing to start a steam turbine?

Ans. Open the throttle slightly and allow a small volume of steam to flow through in order to warm the turbine.

483. What should be done next?

Ans. Start the auxiliary oil pump.

484. What are the principal precautions to be observed when starting a steam turbine?

Ans. To see that the turbine is properly warmed, also to be certain that the oil is circulating freely through the bearings.

485. What type of turbine is the Hamilton-Holzwarth steam turbine?

Ans. It is an impulse turbine.

486. Describe in brief its construction?

Ans. There are no balancing pistons in this machine, the axial thrust of the shaft being taken up by a thrust ball-bearing. The interior of the cylinder is divided into

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a series of stages by stationary discs which are set in grooves in the cylinder and are bored in the center to allow the shaft, or rather the hubs of the running wheels that are keyed to the shaft, to revolve in this bore.

487. In what respect does this turbine resemble a compound reciprocating engine?

Ans. The steam is first admitted to the high pressure casing, and from there it passes into the low pressure casing, which is larger in diameter.

488. Describe the action of the steam upon the blades?

Ans. The expansion of the steam takes place entirely within the stationary blades, which also change the direction of its flow, distributing it to the running vanes.

489. What additional function do the stationary vanes perform?

Ans. They take the back pressure, thus acting as balancing pistons.

490. What type of governor has this turbine?

Ans. The spring and weight type.

491. How are the bearings lubricated?

Ans. The oil is forced into the bearings under pressure by an oil pump.

492. Of what type is the Rateau steam turbine?

Ans. It is an impulse turbine having wheels of thin plates, slightly conical.

493. How is the rotor balanced?

Ans. The same pressure exists on both sides of each rotating wheel.

494. Does the steam act by velocity or pressure?

Ans. By velocity in this case.

495. What are the essential features of the Reidler-Stumpf steam turbine?

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Ans. The peculiar form of bucket, and the parallel return of the steam.

496. What is meant by parallel return of the steam?

Ans. The steam enters the buckets through nozzles, and is deflected through an angle of 180 degrees, thus leaving the rotating buckets in a direction parallel to that of its entrance.

497. Describe the action of the steam within the Reidler-Stumpf turbine.

Ans. Instead of escaping after having once passed through the buckets, it is caught by the guides or stationary buckets and returned to the wheel; this process being repeated again, and again until all of the energy in the steam has been made to do work.

498. How many types of this turbine are there?

Ans. Two, viz.: The single flow, and the double flow.

499. How is the highest efficiency obtained in the operation of the steam turbine?

Ans. By allowing the exhaust steam to pass into a condenser.

500. Is it possible to maintain as high vacuum with the turbine as with a reciprocating engine?

Ans. Experience demonstrates that a higher vacuum may be maintained in the condenser of a turbine than is possible with reciprocating engines.

501. What kind of condensing apparatus may be used with steam turbines?

Ans. Any one of the modern improved types.

502. What is required in order to maintain a high vacuum in any type of condenser?

Ans. That all entrained air be excluded.

503. How may this be accomplished?

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Ans. By means of a dry air pump.

504. In what manner does the dry air pump differ from an ordinary air pump?

Ans. The dry air pump handles no water, and the clearances are made as small as possible.

505. To what extent does the steam turbine expand its working steam?

Ans. To within one inch of the vacuum existing within the condenser.

506. Is the steam turbine adapted to the use of superheated steam?

Ans. It is. Highly superheated steam may be used, and a high vacuum maintained.

507. Is the water of condensation from turbines desirable for boiler feed?

Ans. It is, for the reason that it contains no lubricating oil, and is a comparatively pure water.

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The Gas Engine

508. In what respect does the gas engine differ from the steam engine structurally?

Ans. It is a much more ponderous machine than a steam engine of equal output, and usually requires a much heavier crank shaft.

509. Why should this be?

Ans. Because the ordinary four-stroke-cycle, gas engine has only one working stroke in four, and requires four times as much cylinder area for a given amount of work, as would a steam engine for the same work.

510. Define the difference between a single acting four stroke cycle and a double acting or two stroke cycle gas engine in their operation.

Ans. In the four stroke engine two revolutions of the crank are required for one cycle. In the double acting or two stroke, the cycle is completed in one revolution of the crank.

511. Why are gas engine crank shafts made larger in proportion than those of steam engines?

Ans. In order that they may withstand the increased torsional strains.

512. What causes the pressure behind the piston of the gas engine?

Ans. The combustion within the cylinder of a charge of gas and air properly mixed to form an explosive, and admitted at the proper moment.

513. When is this proper moment?

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Ans. When the piston is at the end of its instroke ready to start outward.

514. Define the stages of a four cycle engine.

Ans. First, induction; during an out stroke of the piston, air and gas are drawn into the cylinder in the proper proportions. Second, compression; on the return stroke the piston compresses this combustible mixture into the clearance space. Third, explosion; ignition of the compressed charge causes a rapid rise of pressure and subsequent expansion of products. Fourth, expulsion; the expanded gases are expelled by the returning piston.

515. Define the stages of a two cycle gas engine.

Ans. First, compression of the charge. Second, ignition, explosion, and expansion, and at the end of the stroke the expanded products are expelled, and the cylinder filled by another charge of air and gas under pressure.

516. How many compression chambers are needed for the two cycle gas engine?

Ans. Two; for the reason that this type of gas engine requires two cylinders, either side by side, or tandem, and the charge of gas and air is being received in one cylinder, while the previous charge in the other cylinder is being compressed preparatory for explosion.

517. How is the usefulness of the gas engine as a prime mover made apparent?

Ans. By the fact that a suitable power gas may now be produced from almost any kind of commercial fuel.

518. What are the relative volumes of gas and air required for combustion in a gas engine?

Ans. This depends upon the kind of gas. Natural gas requires 10 to 12 cu. ft. of air per cubic feet of gas, while producer gas requires equal volumes of gas and air.

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519. Is blast furnace gas suitable for fuel gas?

Ans. Yes, because it is slow burning, thus permitting high compression.

520. To what pressures may it be compressed?

Ans. 160 to 200 lbs. per sq. in.

521. Is there as much heat in a given volume of blast furnace gas as in the same volume of natural gas?

Ans. No, there is about 40 per cent less.

522. How is the charge of gas and air drawn into the cylinder of a gas engine?

Ans. By the suction of the piston.

523. What precaution should be observed regarding the admission of the air and gas?

Ans. The air should be pure and free from dust, and the gas should not contain tarry matters if it can be avoided.

524. How are the induction valves usually set?

Ans. So that the first portion of the charge is air only, then air and gas, and finally air with a small quantity of gas.

525. How is the air valve controlling the entry of the entire charge adjusted?

Ans. It is set to open well in advance of the inner dead center of the engine, and is kept from closing until after the outer dead center.

526. Why is this valve so set?

Ans. In order that the full effect of the momentum imparted to entering gases at the highest rate of piston speed may be utilized.

527. Upon what does the allowable compression pressure depend?

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Ans. Upon the relative proportions of hydro-carbon gases, and hydrogen contained in the mixture.

528. What per cent of hydrogen is considered within the limits of safety?

Ans. Not over 7 per cent.

529. What are the usual compression pressures carried with blast furnace gas?

Ans. 200 lbs. per sq. in.

530. What pressure may be safely carried when producer gas is used?

Ans. From 150 to 200 lbs. per sq. in.

531. If illuminating gas is used, what is the maximum safe pressure?

Ans. 120 lbs. per sq. in.

532. How is the cylinder cooled and cleaned?

Ans. By the injection of water or cold air through the clearance spaces, and valve ports during the charging stroke, or by pressure during compression.

533. What other methods are available for cooling the cylinder and piston rod?

Ans. By means of a water jacket that surrounds the cylinder. The piston rod may be hollow and water circulated through it.

534. How is the charge of gas and air ignited?

Ans. Formerly by hot tubes of porcelain or hecnum, which are still used to some extent, but at the present day electrical ignition devices are used principally.

535. What kind of electrical devices are used for this purpose?

Ans. Primary batteries, storage batteries, and magneto machines, or the current may be taken from the lighting, or power circuit.

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536. How many types of primary batteries are in common use?

Ans. Two—Dry and wet batteries.

537. What are the elements commonly used in the wet battery?

Ans. Carbon and zinc immersed in a jar or cell containing a solution of sal ammoniac, or sulphate of copper.

538. Describe the copper oxide battery.

Ans. It consists of a plate of copper oxide, and a zinc plate, both being immersed in a solution of caustic potash.

539. What is the usual voltage of these cells?

Ans. From 1 to 2 volts per cell.

540. Describe in brief the construction of the storage cell?

Ans. It consists of gridded frames of lead, part of which are filled with red lead for the positive plates, and those for the negative plates are filled with litharge, all being immersed in a solution of 6 parts of water to 1 part of sulphuric acid.

541. How is a dry battery made?

Ans. A round zinc case forms one of the elements, and a piece of carbon in the center of the case forms the other element.

542. Are there any other ingredients?

Ans. Yes—A mixture of powdered manganese, carbon, and flour is packed around the carbon, while the rest of the can is filled with a plaster mixture of oxide of zinc and flour, and the whole is soaked in a solution of sal ammoniac and zinc chloride.

543. In what manner does the electric current ignite the charge of gas in the cylinder?

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Ans. By means of the jump spark caused by alternately making and breaking the circuit.

544. What is one of the most important features connected with ignition?

Ans. To see that ignition occurs at the proper moment.

545. At what point in the stroke of the piston should ignition occur?

Ans. This depends upon the quality of the gas used. With the maximum allowable percentage of hydrogen, ignition should not occur until after the piston has passed the inner dead center. Otherwise the result will be violent shocks, and strains upon the working parts.

546. Do high initial explosions create the most powerful efforts behind the piston?

Ans. They do not.

547. What are the usual terminal pressures for gas engines?

Ans. 25 to 30 lbs. above atmospheric pressure.

548. How is the horse power of a gas engine calculated?

Ans. Usually from the same formula used in connection with the steam engine, and the computation is based upon the mean effective pressure developed at each explosion.

549. What percentage of the total calorific value of the coal is usually converted into useful work with the steam engine?

Ans. From 5 to 10 per cent.

550. What percentage of the energy contained in the fuel is it possible to utilize with a modern gas-driven unit?

Ans. From 16 to 20 per cent.

551. How many type of apparatus are in use for the production of gas for power?

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Ans. Three: the suction producer, the steam pressure producer, and the induced down draft producer.

552. What kind of fuel must be used in the suction, and steam pressure producers?

Ans. Coke, or anthracite coal.

553. What kind of fuel is the induced down draft producer adapted for?

Ans. Bituminous coal.

554. How may gas engine efficiency be expressed?

Ans. In terms of heat value.

555. Is there any difference of importance between a gas engine, and a gasoline or oil engine?

Ans. None of any importance. A gas engine may be easily converted into a gasoline engine, or vice versa.

556. Wherein lies the principal difference between the two kinds of engines?

Ans. In the gas engine proper the gas is supplied to the cylinder by the producer. In the gasoline engine the gas is generated within the cylinder, from a charge of gasoline.

557. How may the action of the gas within the cylinder of a gas engine be ascertained?

Ans. By means of diagrams taken with an indicator.

558. Is there any difference between a steam engine indicator, and an indicator adapted for gas engines?

Ans. None in principle. The gas engine indicator is made somewhat stronger owing to the high pressures used.

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Air Compressors

559. What is one of the results of compressing air?

Ans. The development of heat.

560. What amount of work is lost by the development and dissipation of this heat?

Ans. The work represented by the mechanical equivalent of the heat developed.

561. Mention another cause of more or less lost work in air compression?

Ans. Friction of the air in the pipes through which it is conveyed.

562. By what two methods is air compression generally accomplished?

Ans. Isothermal, by which the heat of compression is carried away as fast as developed; and adiabatic, by which no heat is removed from the air.

563. Which of the two is the ideal method of compression?

Ans. The isothermal.

564. Is it possible of attainment?

Ans. Not entirely.

565. What may be said of the adiabatic method?

Ans. It is one which should be avoided as much as possible.

566. What are the actual results secured in the best compressors?

Ans. They are intermediate between the two methods just mentioned, but nearer to the second method.

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567. Upon what does the efficiency of an air compressor depend principally?

Ans. Upon the effectiveness of the cooling devices.

568. How many practical methods of removing the heat of compression are there?

Ans. Two—jacket cooling, and intercooling.

569. Is jacket cooling of the compressor-cylinder effective?

Ans. Not entirely, except with single-stage compression.

570. What is an intercooler?

Ans. It is a cooling device interposed between the cylinders of a compound or multi-stage machine, through which the air passes on its way from one cylinder to the next one.

571. Describe the process of compression by the multi-stage method?

Ans. A multi-stage compressor has two or more cylinders, the intake or low pressure cylinder being the largest in diameter, and in which the air is first compressed to a low pressure, and then passed on into the next cylinder which is of smaller diameter, where the air is compressed to a still higher pressure, and so on in increasing ratio.

572. How should the cylinder ratios be proportioned?

Ans. So that the M. E. P. and the final temperature are equal in all the cylinders.

573. Describe the construction of an intercooler?

Ans. It usually consists of a nest of tubes through which cold water circulates, and between which the stream of air passes.

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574. Which method, single-stage, or multi-stage, approaches nearest to the theoretical ideal?

Ans. The multi-stage, with intercoolers.

575. Mention another point in favor of multi-stage compression?

Ans. It permits a higher piston speed, thus economizing in steam.

576. What is one of the greatest difficulties encountered in air power transmission?

Ans. Freezing of the moisture in the air, either in the pipe line, or at the exhaust ports of the air motors.

577. How may this condition be avoided to a large extent?

Ans. By the proper cooling of the air during compression, which will precipitate the moisture, which may then be withdrawn by drain pipes.

578. What would be the resultant temperature of air compressed from atmospheric pressure, and 60° Fahr., to a final pressure of 100 lbs., provided there was no cooling device?

Ans. 484° Fahr.

579. What effect would this have upon the cylinder lubricant?

Ans. It would be burned, and be useless.

580. What would be the temperature of the same volume of air if compressed in the first, or intake cylinder of a multi-stage machine to a pressure of 25 lbs.?

Ans. 233° Fahr.

581. If passed through an intercooler on its way to cylinder No. 2, what would its temperature be?

Ans. It would be brought back to its original temperature of 60° Fahr. and enter the second cylinder under a pressure of 25 lbs.

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582. What would the temperature of the same air be if compressed in cylinder No. 2 from 25 lbs. to 100 lbs. pressure?

Ans. It would be but little in excess of that attained in the first cylinder, viz., 233° Fahr.

583. Why would it not attain the temperature stated in the answer to question 578, viz., 484° Fahr.?

Ans. Because the heat of compression is a function of the number of compressions, and practically independent of the initial pressure.

584. Why is air compression at high altitudes more expensive than at sea level?

Ans. Because the capacity of the compressor decreases in a greater ratio than does the power necessary to compress.

585. At an elevation of 10,000 ft. above sea level, what is the increase in expense?

Ans. Over 20 per cent.

586. What should be the first care in the installation of an air compressor?

Ans. To provide a suitable foundation.

587. What precautions should be observed in the piping?

Ans. First, there should be as few L's as possible, and second, all pipes should be thoroughly cleaned before starting the compressor; third, allowance should be made for expansion.

588. What is the function of the unloader on the Ingersoll-Rand air compressor?

Ans. To take the load off the air piston when the pressure reaches the desired point.

589. What is the function of the regulator?

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Ans. To regulate the supply of steam to the steam end of the compressor.

590. What type of air inlet valves is this compressor equipped with?

Ans. Piston inlet valves.

591. Describe the action of these valves?

Ans. The air enters and passes through the piston, thus tending to keep it cooled.

592. What is the function of the Mason pump governor, with which some air compressors are equipped?

Ans. To maintain a constant speed regardless of the load.

593. What kind of inlet valves is the Dallett air compressor fitted with?

Ans. Either mechanically operated valves, or automatic poppet valves, as desired.

594. With what type of valves are the Allis-Chalmers air compressors usually equipped?

Ans. Rotary valves for the inlet, and single-beat poppet valves for the discharge.

595. How are the inlet valves operated?

Ans. By an eccentric on the main shaft, and a wrist plate.

596. What other type of valve-gear are some of these compressors equipped with?

Ans. Both inlet, and discharge valves are actuated by independent eccentrics on the main shaft.

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Refrigeration

597. Of what does the process of refrigeration consist?

Ans. In the abstraction of heat from a substance.

598. Describe a freezing mixture that will give a temperature of 67 degrees below zero.

Ans. A mixture of one pound of calcium chloride, and 0.7 lbs. of snow.

599. Upon what are the theory, and practice of mechanical refrigeration based?

Ans. Upon the two first laws of thermo-dynamics.

600. What is the first of these laws?

Ans. Mechanical energy and heat are mutually convertible.

601. Define the second law.

Ans. An external agent is necessary to complete or bring about this transformation.

602. Is heat generated by compression, or by any other means?

Ans. It is not generated but developed, because there is a fixed amount of heat in the universe which can neither be increased nor diminished.

603. What is the result of compressing one pound of air at 70 degrees temperature and at atmospheric pressure, to one half its original volume?

Ans. An increase in its static pressure, also an increase in its temperature.

604. In order that the higher pressure may be maintained, as the temperature is reduced, what is necessary?

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Ans. A small additional quantity of air will have to be forced into the compressor cylinder.

605. If the pound of compressed air be allowed to expand in a cylinder what will be the result?

Ans. A portion of the heat developed by compression will be given up.

606. What can be said of the mechanical work done by this air in its expansion?

Ans. In amount it is exactly the same as that done upon it during its compression.

607. How is the temperature of a body or substance reduced?

Ans. By transferring more or less of the heat contained in the body to some other substance or body.

608. What work is demanded of a refrigerating machine?

Ans. To extract heat from a body, and by the expenditure of mechanical energy to sufficiently raise the temperature of this heat to admit of its being carried away by a suitable external agent, usually water.

609. How may a refrigerating machine be defined, and what is its main function?

Ans. As a heat pump, its main function being the abstraction of heat from the body to be cooled, and transferring that heat to a cooling agent.

610. How may the various devices for refrigeration and ice making be classified?

Ans. Under five principal heads.

611. Explain the action of apparatus belonging to class one.

Ans. Heat is abstracted from the body to be cooled, by the dissolution or liquefaction of a solid, as for instance the cooling of water with ice.

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612. Describe the vacuum system?

Ans. The abstraction of heat is effected by the evaporation of a portion of the liquid to be cooled, the process being assisted by an air pump.

613. How is refrigeration effected in machines belonging to the third class?

Ans. By the evaporation of a separate refrigerating agent, which is subsequently restored to its original physical condition by mechanical compression and cooling.

614. Describe the fourth or absorption system.

Ans. Heat is abstracted by the evaporation of a separate refrigerating agent, under the direct action of heat, which agent again enters in solution with a liquid.

615. Describe the action of machines belonging to the fifth class, known as cold air machines?

Ans. Air, or other gas is first compressed, then cooled, and afterwards permitted to expand while doing work.

616. What two systems have come into general use in the United States?

Ans. The ammonia compression system, and the ammonia absorption system.

617. What are the three distinct stages in the compression system?

Ans. Compression, condensation, and expansion.

618. What is the refrigerating agent or medium used in the compression system?

Ans. Anhydrous ammonia.

619. Of what does ammonia consist, and what is its chemical formula?

Ans. One part of nitrogen, and three parts of hydrogen. Its chemical formula is NH_3.

620. Under what two conditions may gaseous ammonia be liquefied?

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Ans. At a pressure of 128 lbs. per sq. in., and a temperature of 70° Fahr., or a pressure of 150 lbs. and a temperature of 77° Fahr. It may also be liquefied by cold if its temperature be reduced to 85.5° Fahr. below zero.

621. To what pressure is gaseous ammonia usually compressed?

Ans. From 125 to 175 lbs. per sq. in.

622. Of what does a compression plant consist?

Ans. Of a high pressure system made up of a condensing coil surrounded by cooling water, and a low pressure system consisting of an evaporating coil surrounded by brine, or open to the room to be cooled.

623. What takes place during compression?

Ans. The latent heat of the vapor is converted into active, or sensible heat.

624. How is the vapor condensed, or liquefied?

Ans. It is forced into and through the condenser coils which are submerged in a body of cold water, or over which cold water is flowing, and the sensible heat developed during compression is thus transferred to the cooling water.

625. How are the refrigerating qualities of the ammonia in its liquefied state utilized?

Ans. It is allowed to pass in small quantities from the condenser into pipe coils placed in the rooms to be cooled, when it again expands into a vapor, and takes up an amount of heat exactly equivalent to that given up during condensation.

626. After being expanded into vapor, what becomes of it?

Ans. It is drawn back into the compressor, again compressed, condensed, and expanded, the cycle of operations being repeated indefinitely.

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627. How many, and what are the systems of refrigeration by compression?

Ans. Two—the wet system, and the dry.

628. Describe the theory of the wet system.

Ans. The ammonia vapor is cooled by the injection into the compressor cylinder of a small quantity of liquid ammonia at the beginning of each stroke, and it is carried from the cooling room back to the compressor in a saturated state. It is thus kept in contact with a small portion of its originating fluid, and is kept comparatively cool.

629. Upon what does the pressure of steam in a boiler depend?

Ans. Upon its temperature, which is always the same as that of the water in the boiler.

630. What are the relations of temperature and pressure in the case of steam while in contact with the originating water?

Ans. They are interdependent.

631. What is the result if the steam is superheated?

Ans. It may still be of the same pressure, but its temperature will be higher.

632. What results from the compression of a dry gas without cooling?

Ans Its temperature may be much higher than that corresponding to its pressure.

633. What does the Adiabatic curve as traced by the indicator represent?

Ans. The compression, or expansion of a gas without loss or gain of heat.

634. Describe in brief the construction of the cylinder heads, and valves in the Linde ice machine.

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Ans. The piston and cylinder heads are spherical, and of the same radius, and the valve discs conform to this radius.

635. What is the clearance between piston and cylinder head?

Ans One thirty-second of an inch.

636. How is the piston lubricated?

Ans. In a large measure by the moisture in the ammonia vapor.

637. In the De La Vergne refrigerating machine how is the heated gas cooled?

Ans. By passing it through coils of pipe surrounded by running water.

638. How many valves has the Triumph ice machine?

Ans. Five, three suction valves, and two discharge valves.

639. What advantage is said to be gained by the use of the third suction valve?

Ans. That it tends to increase the economy of the machine.

640. Describe the construction of a double pipe ammonia condenser.

Ans. It consists of two series of coils, one within the other.

641. How many methods are there of utilizing refrigeration?

Ans. Two; the brine system, and the direct expansion system.

642. Describe in brief the brine system.

Ans. The coils of pipe in which the ammonia is expanded are submerged in a solution of salt, or calcium chloride. This brine after being reduced to a low tempera-

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ture is pumped through coils of pipe in the rooms to be cooled.

643. Describe the direct expansion system.

Ans. The expansion coils are placed in the rooms to be cooled, and the cooling is effected directly by the expansion of the ammonia.

644. Which one of the two systems is the most efficient?

Ans. The direct expansion system.

645. Mention a few of the advantages that this system has over the brine system.

Ans. First—All intermediate agencies are dispensed with. Second—The whole plant is much simpler. Third—A larger expansion surface.

646. By what two systems is ice made or manufactured?

Ans. The can system and the plate system.

647. Mention other refrigerating agents besides ammonia that may be used in the compression system?

Ans. Ether, methyl-chloride, sulphurous acid, and carbonic acid.

648. How is refrigeration effected in the absorption system?

Ans. By the continuous distillation of ammoniacal liquor.

649. What advantage appertains to the absorption system?

Ans. The bulk of the heat required for the work is applied direct without being transformed into mechanical power.

650. What pressure is usually maintained in the generator?

Ans. 150 lbs. per sq. in.

651. Mention the more important features of the absorption machine?

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Ans. The expansion valve, the absorber, and the strength of the liquor.

652. Upon what does the efficiency of the machine mostly depend?

Ans. Upon the condition of the absorber. If it is cool and free from air, or poor gas, better results will be realized.

653. What should be done if one side of the absorber should get warmer than the other?

Ans. The spray valve should be turned down slightly, say one-eighth of a turn.

654. Mention one of the troubles in the operation of this system.

Ans. A filling up of the coils with scale and dirt.

655. What is the remedy in such cases?

Ans. Stop the machine once a week, drain the coils, and blow them out with compressed air.

656. How is anhydrous ammonia formed?

Ans. By condensing ammonia gas to a liquid, and applying pressure.

657. Under atmospheric pressure, what is the boiling point of anhydrous ammonia?

Ans. 28.5 degrees delow zero Fahr.

658. What is the specific gravity of liquid ammonia compared with water?

Ans. At 32° Fahr. it is about $\frac{5}{8}$ that of water, or 0.6364.

659. What is its latent heat of evaporation?

Ans. At 32 degrees temperature it is 560 thermal units.

660. If evaporated at 32° Fahr. and atmospheric pressure, how much space will one pound occupy?

Ans. Twenty-one cubic feet.

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Elevators—Electric and Hydraulic

661. What are the essential parts of the Otis traction elevator?

Ans. A traction motor driving sheave, and a pair of electrically released brake shoes.

662. What type of electric motor is used in the Otis traction elevator?

Ans. A slow speed shunt-wound motor.

663. What is the principal function of the armature shaft besides carrying the armature?

Ans. To support the load.

664. How, then, is the drum, or sheave driven?

Ans. By means of projecting arms from the armature, that engage with similar arms projecting from the drum.

665. Describe the system of safety devices with which this elevator is equipped?

Ans. There are two groups of switches located respectively at top and bottom of the shaft, each switch in series being opened one after the other by the car as it passes. This retards the speed and finally brings the car to stop, applying the brake, independent of the operator in car.

666. Are there any other safeties besides this?

Ans. Yes—speed governors, wedge clamps for gripping the guides, and potential switches.

667. Describe in general terms the construction of the Otis geared traction elevator?

Ans. A multi-grooved driving sheave around which the cable works. The sheave is mounted upon a shaft driven

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by geared wheels actuated by a right and left hand worm cut on the armature shaft.

668. What advantage is gained by the use of the double screw, or worm?

Ans. The elimination of all end thrust.

669. With what kind of brake is this machine equipped?

Ans. A mechanically applied, and electrically released brake.

670. What type of motor is used?

Ans. Compound-wound—speed 800 R. P. M.

671. When is the series field of this motor used?

Ans. Only at starting.

672. Why?

Ans. To obtain a highly saturated field in the shortest possible time.

673. How is a gradual slowing down of speed of car obtained with this elevator?

Ans. By throwing a low resistance field across the armature, thus providing a dynamic brake action.

674. What kind of current is used for operating electric elevators?

Ans. Either alternating, or direct current.

675. How is the transmission of current to the motor of an electric elevator controlled?

Ans. By means of an electric magnet controller operated through the switch in the car.

676. How may considerable power be wasted in the operation of electric elevators?

Ans. By careless handling—making unnecessary stops and starts, or too sudden stops or starts.

677. Briefly, of what does the mechanism of a hydraulic elevator consist?

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Ans. A cylinder and piston with one or more rods connected to a crosshead which carries the sheaves over which run the lifting cables from which the car is suspended.

678. What moves the piston?

Ans. Water under pressure admitted by means of suitable valves causes the piston to move from one end of the cylinder to the other, and back again.

679. How is this motion transmitted to the elevator car?

Ans. By means of the sheaves mounted on the crosshead which carry the lifting cables.

680. In what position is the cylinder placed?

Ans. Either vertical alongside the hatchway, or horizontal in the basement of the building.

681. How are the valves of a hydraulic elevator operated?

Ans. In some cases by a hand rope passing through the car and over small sheaves at the top and bottom of the hatchway, and connected with the main valve in the basement. By pulling this rope down the valve is opened, and the car will ascend, while pulling the rope up will cause the car to descend.

682. What safety devices are attached to this type of elevator?

Ans. Two balls are attached to the hand rope, one near the bottom, and the other near the top. These balls come in contact with the top, or bottom of the car, according as it is going up or coming down, and being carried along they, of course move the cable, thus actuating the valve, bringing the car to a stop.

683. Is this device safe, and automatic?

Ans. It is.

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684. Mention another safety device connected with hydraulic elevators.

Ans. Safety clamps under the control of a speed limit centrifugal governor which causes the clamps to grip the guides and thus hold the car.

685. How is this safety governor operated?

Ans. By means of a small cable connected with the car and moving with it, which passes over the sheave pulley of the governor.

686. Why are some elevator pistons fitted with two piston rods?

Ans. To prevent the piston, and crosshead from turning or twisting, and also to strengthen the construction.

687. What other methods are used for manipulating the water valve, besides the one already described?

Ans. Running ropes, and standing ropes, either of which may be operated by means of a lever, or wheel in the car.

688. Do these devices directly operate the main valve?

Ans. No. They operate a small valve called the pilot valve.

689. What is the function of the pilot valve?

Ans. When opened it admits the pressure water to a small cylinder with piston connected to the main valve stem. This actuates the main valve, which in turn, by its movement, closes the pilot valve.

690. Upon what does the amount of opening given the pilot valve, and consequently the main valve depend?

Ans. Upon the distance the lever in the car is moved from central position.

691. What is meant by central position of lever?

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Ans. That position in which there is no flow of water either into or out of the cylinder, and the car is moving only by its momentum.

692. What is the result of moving the lever too quickly to central position when the car is moving at a high rate of speed?

Ans. The motion of the car will be arrested with a sudden jerk.

693. How many kinds of horizontal hydraulic elevators are in use?

Ans. Two. One is the pushing, and the other the pulling type.

694. Describe the action of the pushing type?

Ans. The car being at the bottom, the pressure water is admitted behind the piston which then moves, pushing the crosshead and cable sheave and lifting the car.

695. Describe the action of the pulling type?

Ans. It is the opposite of that just described.

696. Is there much difference in the valve mechanism of the horizontal, and vertical types of hydraulic elevators?

Ans. Very little except a few minor details.

697. What is meant by a double-deck machine?

Ans. Where the floor space is restricted two, and sometimes three or four machines are mounted one above the other.

698. What water pressure is usually carried in operating the types of hydraulic elevators that have hitherto been described?

Ans. Pressures not exceeding 200 lbs., the average being 150 lbs. per square inch.

699. Are any higher pressures than this being used for operating hydraulic elevators?

Ans. Yes. Pressures of 700 to 800 lbs. and higher.

700. Why are such high pressures used?

Ans. Owing to increased height of buildings, and the demand for high car speed.

701. What advantage, other than high speed, is gained by the use of high pressure elevators?

Ans. A reduction in the size of the valve mechanism, piston areas and piping.

702. Mention another advantage in connection with the high pressure system?

Ans. A reduction in the loss by friction of the water passing through the pipes, owing to reduced areas.

703. What is the percentage of loss due to this cause?

Ans. In low pressure machines from 10 to 30 per cent, and in high pressure machines from 5 to 6 per cent.

704. Describe in general terms the construction of the cylinder and piston of a high pressure machine.

Ans. The cylinder area is reduced to about one-eighth that of the low pressure type, and the piston is a solid plunger.

705. How is the pressure maintained?

Ans. The pump forces water into the lower end of the accumulator, an air-tight tank, which is also weighted. From the accumulator a pipe runs to the main valve.

706. Describe in general terms the construction and operation of the direct-acting plunger elevator.

Ans. A cylinder is set vertically in the ground under the center of the car, and the length of it is slightly greater than the travel of the car. In this cylinder is a plunger of the same length, which carries the car. Water under pressure is forced into the cylinder and thus lifts the car, and allowed to run out at the top when the car descends. The cylinder is about two inches larger in diameter than the plunger, and is always full of water.

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707. What is the usual diameter of the plunger?

Ans. 6½ to 7 inches.

708. How is it constructed?

Ans. Of lengths of highly polished steel pipe, joined together with an internal sleeve, and having its lower end closed.

709. What pressure is ordinarily used on this type of elevator?

Ans. 150 to 200 lbs. per square inch.

710. How is the top of the cylinder arranged?

Ans. With a packing gland through which the plunger moves up and down.

711. What types of elevators are in general use for passenger service?

Ans. Electric and hydraulic.

712. How is the capacity of a pump usually expressed?

Ans. In gallons of water per minute raised to a given height.

713. What is meant by the head under which a pump works?

Ans. The vertical distance between the surface of the water in the suction reservoir, and that in the discharge reservoir.

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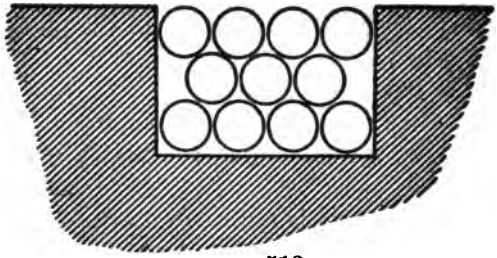

FIG. 512

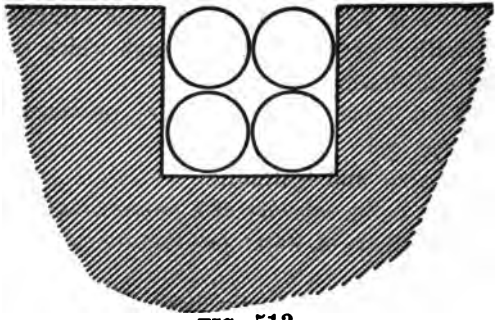

FIG. 513

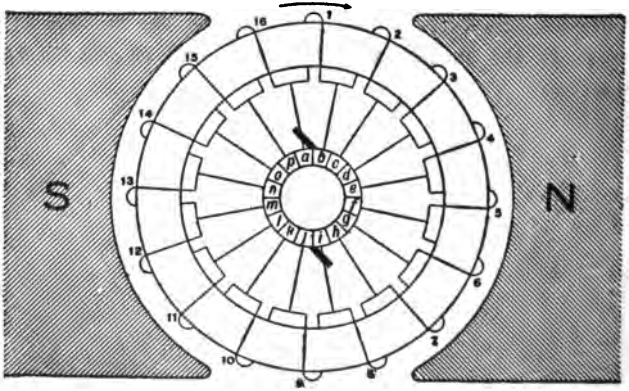

FIG. 514

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714. What is electricity?

Ans. Electricity is an invisible agent. Its exact nature is not very well known, although the laws governing its action, the methods of controlling it, and the effects produced by it are becoming well known.

715. Is it correct to use the term quantity with reference to electricity?

Ans. It is. We may use terms to designate definite quantities of electricity, passing through a conductor, in the same way that we speak of gallons of water flowing through a pipe.

716. Is it proper to assume that there are large quantities of electricity stored for future use, in a manner similar to water?

Ans. It is not, except in a limited sense, as in storage batteries.

718. Define the doctrine of the conservation of energy.

Ans. The total quantity of energy in the universe is unalterable. When energy is expended, or disappears in one form, it must reappear in another form.

719. In accordance with this doctrine, what would be the proper term to apply to electricity with reference to the physical requirements of man?

Ans. It is a useful agent for the rapid transmission of stored up energy in fuel, water falls, etc.

720. What is the practical unit of quantity used in speaking of electricity?

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Ans. The coulomb. It is that quantity of electricity that would pass in one second through a circuit carrying a current of one ampere.

721. What is an ampere?

Ans. It is the unit of volume, or rate of flow. A current of one ampere will flow through a circuit whose resistance equals one ohm, when the electro-motive force, or pressure behind it equals one volt.

722. What is a volt?

Ans. The volt is the unit of electro-motive force, and represents a pressure that will cause the flow of one ampere through a circuit in which the resistance equals one ohm.

723. What is an ohm?

Ans. The ohm is the practical unit of electrical resistance. It is that amount of resistance that would limit the flow of electricity under an electromotive force of one volt, to a current of one ampere, or to a discharge of one coulomb per second. It equals the resistance of a column of mercury one sq. millimetre in area of cross section, and 104.9 centimetres in length.

724. What is the unit of work?

Ans. The foot pound.

725. What is the unit of power, or rate of doing work?

Ans. The foot pound, per second.

726. How is the amount of work that electricity is capable of doing, measured?

Ans. By the volt-coulomb, or Joule. The amount of electrical work per second is equal to the volt ampere, or watt.

727. What amount of power developed is represented by the watt?

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Ans. 44.25 foot-lbs. of work per minute, or 0.7375 foot-lbs. per second.

728. What is a magnet?

Ans. A mineral consisting of a combination of iron and oxygen.

729. What is the chemical formula of a magnet?

Ans. Fe^3O^4.

730. What is a permanent magnet?

Ans. A piece of steel that has been charged with magnetism, and retains it.

731. What is meant by the poles of a magnet?

Ans. All magnets tend to point north and south, the same end always pointing in the same direction; hence the end pointing north is called the north pole, and the end pointing south is termed the south pole.

732. What peculiar characteristic attaches to the poles of magnets?

Ans. The north poles of two magnets tend to repel each other, and the same is true of the south poles. But the north pole of one magnet attracts the south pole of another, like repels like, and unlike attracts unlike.

733. What is an electro magnet?

Ans. A bar of iron surrounded by a coil of wire through which an electric current is passing.

734. What are lines of force?

Ans. They are certain imaginary lines passing through the steel of the magnet from its south pole to its north pole, and issuing from the latter they curve around through space and return to the south pole.

735. What is the magnetic circuit?

Ans. It is the path of these lines of force, around and through the magnet. It resembles a closed curve, either a circle, or an ellipse.

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736. Explain the difference between the magnetic circuit and the electric circuit.

Ans. The magnetic circuit, or field of force, that surrounds a magnet is maintained without the expenditure of energy, while on the other hand an electric current passing upon its circuit develops energy, and energy must be expended to maintain it.

737. Are there any other points of difference between the two circuits.

Ans. Yes, the electric current passes through a conductor in intensity proportional to the electro-motive force urging it, while the magnetic circuit passes through air, or a vacuum in proportion to the magneto-motive force urging it.

738. What is meant by the term potential as applied in electric practice?

Ans. Voltage or pressure.

739. What is the law of induction?

Ans. When a conductor is moved in a magnetic field of force so as to cut the lines of force, there is an electro-motive force impressed on the conductor in a direction at right angles to the direction of motion, and at right angles to the direction of the lines of force.

740. What is a dynamo?

Ans. A machine for transforming mechanical energy into electrical energy.

741. How is the field of force maintained in a dynamo?

Ans. By means of electro-magnets.

742. Does not this require the expenditure of energy?

Ans. Yes; a certain amount of energy is indirectly expended.

743. How are dynamos classified?

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Ans. Into two grand divisions, viz., direct current dynamos and alternating current dynamos.

744. What is direct electrical current?

Ans. A current of unchanging direction.

745. What is an alternating current?

Ans. A current that reverses its direction of flow, periodically, from 20 times and upward per second.

746. Name the principal constituent parts of a dynamo.

Ans. The armature, the field, the collecting rings, or commutator, and the brushes.

747. How is electro motive force or current induced in a dynamo?

Ans. By rapidly changing field and armature relations by means of mechanical energy.

748. How is the output of a dynamo stated?

Ans. In Kilowatts equal to 1,000×volts×amperes.

749. How is the output of a motor stated?

Ans. In horse power, equal to Watts intake÷746×efficiency expressed decimally. (Not as a percentage.)

750. What is the voltage of a dynamo? of motor?

Ans. It is the pressure that the generator or alternator delivers at its own terminals. The voltage of a motor is the voltage which should be applied to its terminals in order to develop full horse power.

751. What is full load current of dynamo? of motor?

Ans. Full load current of a dynamo is that current which may be drawn steady for 24 hours without causing any part of the machine to exceed a safe temperature, i. e., 150° Fahr. This applies to factory motors.

752. What is meant by the rating of a dynamo? Of a motor?

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Ans. The product of full load current multiplied by the voltage expressed in Kilowatts is rating of a dynamo. The actual mechanical horse power developed at the pinion of the motor as tested in shop.

753. What is the armature core?

Ans. The sheet iron body which carries the armature winding, and conducts the flux from pole piece to pole piece.

754. What is the armature spider?

Ans. The casting consisting of hub and arms which supports armature core.

755. What are binding wires?

Ans. They are narrow bands of phosphor bronze wire placed around the armature every three or four inches to help bind the winding to the core. They rest on strips of mica, and are sweated with solder all around.

756. What are commutator segments?

Ans. The commutator segments or bars are the copper pieces of which the commutator is built.

757. What are commutator leads?

Ans. They are the ends of the armature winding extending from the core to the lug of the commutator bar.

758. What are pole pieces?

Ans. The end of the magnet core nearest the armature. Usually larger than the core.

759. What are magnet cores?

Ans. The iron inside the field coil.

760. What is the yoke?

Ans. The part of magnetic circuit connecting the magnet cores.

761. What is the pitch of an armature winding?

Ans. It is the number of teeth between the two sides of a formed coil plus one tooth.

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Example: The two sides of a coil are in slots number 3 and 17, then pitch is 14.

762. Is there insulation between winding and core?

Ans. Yes. Mica or fuller board; there is also the tape on coil.

763. What insulation is there between conductors of winding?

Ans. The double cotton covering of each wire makes four thicknesses between conductors.

764. What is the air gap?

Ans. It is the air space between armature and pole pieces. In dynamos it is made as small as possible for efficiency.

In motors it is not made too small because this tends to make the machine spark due to the weak field. In D. C. series motors it is from ⅛ to ¼ of an inch, in A. C. series motor it is smaller, say 1/10 to ⅛ inch.

The larger the air gap of a motor the more the bearings may wear before there is danger of the armature rubbing against the lower pole pieces.

765. What are field spools?

Ans. The brass shells on which the field coils are wound.

766. What is the commutator?

Ans. It is a series of copper bars placed parallel to the shaft, insulated from each other and from the frame of the machine. Each is connected to the winding and current flows from the winding through them to the brushes. It at the same time reverses the connections between the brushes and the winding at the proper times so that the brush always collects current.

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767. What is a collector or slip ring?

Ans. A collector consists of two or more rings of copper placed around the shaft and insulated from it, and each other. Each is connected to a part of the winding. The brushes rest on the rings.

They are used to collect current from a revolving armature style of alternator, to feed current into armatures of rotary converters, or the revolving fields of alternators.

The collector has no corrective influence and passes on the A. C. or D. C. current exactly as it receives it.

Single phase machines have two rings; two, three, and six phase machines have three rings.

768. Is there a difference between no load and full load voltage of dynamos?

Ans. Yes. A shunt dynamo gives highest voltage at no load and lowest at overloads; the series dynamo gives lowest at no load and highest at full load. The compound dynamo is a combination of series and shunt, and gives same voltage at all loads.

An alternator acts like a shunt dynamo.

769. What is a field rheostat?

Ans. It is a resistance in the field circuit which can be varied to change the current, and hence the field strength. This alters the voltage of the dynamo.

770. What are commutated fields?

Ans. In some motors the field coils are arranged in sections so that they may be arranged in parallel, or series, or in combinations.

All coils in parallel give the greatest current and hence slowest speed of motor; all coils in series give the weakest field and the fastest speed.

771. What relation has field strength to the speed of motor?

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Ans. The weaker the field the faster the speed, for the motor must revolve fast to generate its proper counter E. M. F.

772. What relation has armature strength to the speed of motor?

Ans. The greater the armature current the higher the speed.

773. What effect on the power of motor does field, and armature strength have?

Ans. The greater the field and armature current the greater the power.

774. What is a ring winding?

Ans. One which passes over and under around the core, a space being left between the shaft and core to accommodate the winding.

775. What is a drum winding?

Ans. One where all winding is on the outer surface of the core.

776. Upon what does sparkless commutation of current depend?

Ans. (1) The more commutator bars the better, there being less voltage and therefore tendency to spark between bars. The average railway motor has from 100 to 125 bars on commutator.

(2) The fewer the ampere turns on the armature in comparison to the ampere turns on the field the less sparking.

(3) The more turns short-circuited by the brush when touching two or more bars at once, the greater the tendency to spark.

777. What is a shunt field?

Ans. One whose coils are placed as a shunt across the brushes. It carries a small current.

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778. What is a series field?

Ans. One which carries the main, or nearly all the main current, and is placed in series with the armature. A small strip of resistance metal is used sometimes to divert a portion of the main current from the series field.

779. What are Foucault, or eddy currents?

Ans. Local currents set up within the armature, and acting as a hindrance to the generation of useful current.

780. How may the electro-motive force be increased?

Ans. By increasing the speed, or by adding more turns or loops of wire to the armature winding.

781. What is meant by self excitation of a dynamo?

Ans. When the dynamo is standing still, the field magnets become weakly magnetic, but when the armature begins to revolve a few volts of electric current will be sent through the field coils, gradually increasing the magnetic strength until full voltage is reached.

782. What is a series dynamo?

Ans. One in which the same current that travels the main circuit also traverses the field.

783. Explain the action of the shunt dynamo.

Ans. The field circuit is a shunt, and only a portion of the main current passes through it.

784. How are the fields of a compound dynamo excited?

Ans. The fields have two distinct windings; one shunt, and the other series.

785. What advantage pertains to the compound wound dynamo?

Ans. It is practically self-regulating.

786. What is the difference between the dynamo and the electric motor?

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Ans. Practically none in the principles governing the design of the machines. Any dynamo may be used as a motor, and vice versa.

787. State the difference in their functions.

Ans. The dynamo converts mechanical energy into electrical energy, while the motor converts electrical energy into mechanical energy.

788. Upon what does the power to be obtained from a motor depend?

Ans. Two things, viz., the current flowing in its armature coils, and the strength of magnetism developed in its fields.

789. How is the speed of motors controlled?

Ans. By a starting box or rheostat.

790. How may the direction of rotation of a motor be reversed?

Ans. By reversing the current through either the armature or the fields.

791. Upon what principle does the alternating current motor act?

Ans. Upon the principle of induction, having for its main accessory the rotary field.

792. How is a rotary field produced?

Ans. By the use of polyphase currents.

793. Explain the meaning of the term rotary field.

Ans. In a rotary field the rotary action is purely electrical, the poles simply rotating around the circle. There is no rotation of the mechanism of the field.

794. What then is a revolving field?

Ans. A field that revolves around an axis like a wheel.

795. What is the leading characteristic of the direct current?

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Ans. It travels in the same direction of pressure.

796. What is the tendency of the current generated in all dynamos?

Ans. It is alternating in voltage or pressure.

797. Explain the meaning of the term alternating as used in this connection.

Ans. The current starts at a value of zero, rises to a maximum of polarity, descends to a value of zero again, and changing in direction of pressure, rises to a maximum of opposite polarity, from whence it drops to zero again.

798. How then is direct current produced from this alternating current?

Ans. By means of the commutator and brushes on the direct current generator.

799. What is the leading characteristic of the alternating current?

Ans. Its voltage is continually changing at regular intervals from zero to maximum in the direction of opposite polarity.

800. How is this action best represented?

Ans. By wave curves drawn above and below a horizontal line representing zero.

801. In what manner does the action of the alternating current affect the circuit through which it travels?

Ans. The whole circuit passes simultaneously through voltage values of the cycle represented by the wave curve.

802. What is meant by the frequency of an alternating current?

Ans. The number of waves or cycles per second.

803. What does a frequency of 60 mean?

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Ans. It means that the voltage values pass through a complete cycle in one sixtieth of a second, that is 60 cycles per second.

804. What is meant by alternations?

Ans. The number of reversals per minute in the direction of pressure.

805. How many alternations would there be in a current having a frequency of 60?

Ans. 7,200.

806. What is meant by a "period?"

Ans. The time in seconds or fractions of a second required to pass through a complete cycle.

807. What is meant by current wave?

Ans. It means the actual values of the current as shown by the volt-meter and ammeter.

808. Do these equal the values of the theoretical wave curve?

Ans. They do not, reaching about 70 per cent.

809. Why is this?

Ans. It is due to the influence of the iron magnetic circuit caused by the connections of induction motors, arc lamps, and other electrical apparatus.

810. What is meant by effective current?

Ans. The voltage and volume as shown by the volt-meter and ammeter.

811. In what respect is the maximum voltage as shown by the calculated wave curve useful?

Ans. It is useful in testing insulating materials.

812. What is meant by phase in electric practice?

Ans. It denotes the relative position of a current wave, with respect to the wave of electro-motive force producing it.

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813. When is a current in phase?

Ans. When the two waves just mentioned start at zero and reach their maximum values at the same instant.

814. What is meant by lag?

Ans. When the current wave lags behind the voltage wave.

815. What is meant by lead?

Ans. When the current wave is ahead of, or leads the voltage wave.

816. What is the meaning of two and three phase currents?

Ans. When the winding of the armature is such that two or three electro-motive forces in quadrature with each other are simultaneously produced by the generator the currents thus produced may be distributed over four or six conductors, a pair for each current.

817. Is it necessary to have a pair of conductors for each current in two and three phase current work?

Ans. No. By means of the Y winding it is possible to distribute the current over three wires, each wire acting as a main, and return wire for one of the others.

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Armature Design and Construction

818. Can the properties of a dynamo be accurately calculated from any of the formulas given for that purpose?

Ans. No. The accurate design of a new type of dynamo, and an armature as well, is as much a matter of experiment as it is of calculation.

819. Why is this?

Ans. There are so many factors involved in the calculation that cannot be accurately determined until a machine of the exact dimensions of the one under consideration has been built.

820. What are the principal factors that are so troublesome to determine?

Ans. The permeability of the iron, the resistance of the magnetic circuit, the tendency to leakage of the lines of force, the exact proportion of the dead wire, the reaction of the armature, the losses due to *Foucault* currents.

821. Are not the causes of all these losses well understood?

Ans. They are, and it is easy enough to tell what must be done to lessen any or all of them. It is merely their exact value which is indeterminate until the machine in question is in operation.

822. What is the chief precaution which must be taken on this account.

Ans. It is necessary to leave some part of the controlling influences so that they can be readily varied and thus adjust the machine so that it will be exactly right when it is finally finished.

823. How can this best be done?

Ans. Since it is manifestly very troublesome to rewind

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an armature, if perchance too great or too small a number of wires have been placed upon it, the proper factors to be arranged to be variable are: the speed, and the strength of the field. In some cases the speed, even, is not changeable, and the whole duty of compensating for misjudgment in the calculations falls upon variations of the field strength.

824. Can the whole regulation be accomplished in this way?

Ans. It can, and in most cases this is the method relied upon. It is very easily accomplished by this method if we arrange to have the fields magnetized to only a low degree of saturation. By doing this, however, we are led to provide field magnets whose capacity is far in excess of what we believe to be necessary and, therefore, more expensive. So that again in the last consideration it behooves us to experiment before we definitely determine the exact proportion of our dynamo or motor.

825. Are there any formulæ that can be used in determining the exact proportions?

Ans. There are, and they are given below. These will materially assist the student in forming an idea how the different parts can be adjusted to bring about the desired final result. For the following formulæ we shall adopt the attached set of symbols:

Let F=the total number of lines of force, or flux,
V=the number of volts to be generated,
S=the number of slots in the armature,
R.P.S.=the number of revolutions per second,
W=the number of wires per slot.

Then, to find the number of wires necessary per slot where the speed and flux are fixed:

$$W=\frac{10^8\times V}{F\times S\times R.P.S.}$$

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To find the necessary speed where the number of wires, and the flux, are fixed:

$$\text{R. P. S.} = \frac{10^8 \times V}{F \times S \times W}$$

To find the necessary strength of field, where the wires and speed are fixed:

$$F = \frac{10^8 \times V}{S \times \text{R. P. S.} \times W}$$

To find the volts generated:

$$V = \frac{F \times S \times W \times \text{R. P. S.}}{10^8}$$

826. Are these formulæ used in actual practice to determine the size of wire, speed, etc.?

Ans. These formulæ are of value principally in checking up the actual calculations made.

827. How is an armature actually designed?

Ans. In actual practice whenever a new dynamo or motor is to be constructed it is, so to speak, built up around the armature. That is to say, the armature must first be designed, and the other parts made to fit around it.

828. What is the principal consideration to be taken into account?

Ans. In order to deliver a certain current, the number of poles, etc., being fixed, which is with rare exceptions the case, we must use a certain size wire.

829. Is there no choice whatever in the size of wire for a given current?

Ans. There is some choice. In most cases the heating of the wire on the armature determines the size of wire to be used; in other cases it is the drop in potential at the terminals of the armature that governs.

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830. How does the size of wire affect the heating, and the loss of potential?

Ans. Both of these losses, and the troubles occurring from them, are lessened by selecting wires of greater diameter.

831. How do you proceed to calculate the necessary size of wire?

Ans. The number of wires, and the dimensions of the armature for any given purpose can be found by trial calculations only. By this we mean that, unless we are very lucky, we shall have to make a number of calculations, using, perhaps, different dimensions and wires before we get the result that suits us best.

832. Give an example.

Ans. As an example let us take an armature 8 inches in diameter and 8 inches in length and see what it will do for us. Such an armature has a cross-section of 64 sq. inches and, assuming a flux of 30,000 lines of force per square inch, we have a total flux of 1,920,000 lines through the armature. We first find how often one wire must cut this number of lines of force to generate, say, 110 volts. To do this we first divide $110 \times 100{,}000{,}000$ (which is the total number of lines to be cut per second) by the total flux, 1,920,000, and obtain as the result 5728. Next, to get the necessary number of wires to be placed upon the armature, we must divide this quotient (5728) by the number of revolutions the armature makes per second. If our armature revolves at the rate of twenty revolutions per second (1,200 per minute) we shall need one-twentieth of 5,728 wires placed upon it. This amounts to 286. As our armature, 8 inches in diameter, has a circumference of 25.12 inches, this gives us a wire running about 11 per

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inch. If there is to be but one layer, this gives a number 12 wire. As the two sides of the armature are in parallel we have a capacity of 2 times 14.31 amperes according to Table 50. If we decide to use two layers, we can take a No. 6 wire, 5.5 per inch, and obtain a capacity of 56.55 amperes. It may be stated in explanation of the calculations here made that each wire in the course of one revolution of the armature cuts the total flux two times; but as the two halves of the armature are in parallel, each side must produce the full voltage by itself.

833. How much radiating surface is usually allowed per watt of energy used up?

Ans. That depends very much on the work for which the armature is intended. If it is for a railway motor, which is entirely enclosed, and almost constantly in use, it is much more than, for instance, an elevator in a private residence where there is but very little use, and only at long intervals, so that the armature has time to cool off between one run and another. Table 50 is based upon the requirement that there shall be three square inches of radiating surface for each watt of energy expended in the coils.

834. What radiating surface is allowed for each watt expended in the case of an armature?

Ans. This amount varies in different machines, being as low as 1 square inch per watt, and as high as three square inches per watt. About 1.75 square inches per watt expended can be considered as a fair average for armatures and about 3 inches per watt expended for field coils.

835. How is the table referred to (Table 50) made up?

Ans. This table is figured from the formula,

$$I = \sqrt{\frac{RS}{3 \times R}}$$

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R S being the radiating surface, and R the resistance of a unit of length of the wire under consideration. This formula gives the current allowed where the wire is wound in one layer. As we add more layers we must, with each successive layer, reduce the current, so that the square of the current multiplied by the resistance (which equals the watts) shall remain always the same, because increasing the depth of the winding does not affect the radiating surface of the coil.

836. The table gives the carrying capacity only to a depth of six layers; how is the carryng capacity of a greater number of layers to be found?

Ans. To do this we refer to Table 50 and select from the column headed I^2 the number pertaining to the wire in question. This number represents the square of the current permissible with one layer of wire. Divide this number by the number of layers it is intended to use, and extract the square root of the number so found. The result will be the carrying capacity of the wire in question, wound to a depth of that number of layers. As a general guide we may bear in mind that, as we multiply the number of layers by 4, 16, 64, 256, we, each time, decrease by one-half the carrying capacity of the wire. From this we can see that the capacity of the wires after a certain number of layers have been considered, decreases very slowly, though very fast with the first few layers.

837. Is there need of very great accuracy in these calculations?

Ans. Great accuracy is not necessary in these calculations. We can always lengthen our armature a little by adding a few punchings, should the potential be insufficient, and we can always vary the speed and strength of field con-

TABLE 50

TABLE SHOWING CURRENT CARRYING CAPACITY OF DIFFERENT WIRES AT DIFFERENT DEPTHS OF WINDING, 3 SQ. IN. RADIATING SURFACE PER WATT.

B. & S. Gauge.	Diameter bare.	Resistance per foot 140° F.	Diameter D. C. C.	Amperes at different depths of winding layers.						Number of wires per inch.	12
				1	2	3	4	5	6		
4	.2043	.000283	.224	56.28	39.74	32.42	28.12	25.15	22.97	4.45	3166
5	.1819	.000357	.200	47.80	33.46	27.33	23.66	21.16	19.31	5.00	2240
6	.1620	.000450	.180	40.00	28.28	23.08	20.00	17.88	16.34	5.5	1600
7	.1443	.000567	.158	33.40	23.60	19.28	16.67	14.93	13.63	6.3	1114
8	.1285	.000715	.144	28.35	20.04	16.37	14.17	12.68	11.57	7.0	805
9	.1144	.000902	.130	24.00	16.97	13.85	12.00	10.72	9.74	7.7	576
10	.1019	.001137	.117	20.27	14.31	11.70	10.14	9.05	8.24	8.6	411
11	.0907	.001436	.106	17.19	12.12	9.69	8.60	7.68	7.00	9.6	295
12	.0808	.00181	.093	14.31	10.09	8.24	7.14	6.40	5.83	10.7	205
13	.0719	.00228	.084	12.12	8.54	7.00	6.08	5.38	4.89	11.9	147
14	.0640	.00288	.075	10.19	7.21	5.91	5.09	4.58	4.12	13.3	104
15	.0570	.00362	.067	8.60	6.08	4.95	4.30	3.87	3.50	15.0	74
16	.0508	.00458	.059	7.14	5.04	4.12	3.57	3.19	2.91	17.0	51
17	.0452	.00575	.053	6.08	4.30	3.5	3.04	2.64	2.47	19.0	37
18	.0403	.00727	.048	5.09	3.60	2.94	2.54	2.28	2.08	21.0	26
19	.0358	.00916	.044	4.36	3.08	2.52	2.18	1.97	1.78	22.7	19
20	.0319	.01153	.040	3.74	2.64	2.16	1.87	1.67	1.52	25.0	14
21	.0284	.01454	.036	3.14	2.22	1.81	1.57	1.39	1.28	28.0	9.9
22	.0253	.01845	.033	2.66	1.87	1.54	1.33	1.19	1.09	30.3	7.1
23	.0225	.0231	.030	2.28	1.61	1.30	1.14	1.01	.94	33.3	5.2
24	.0201	.0295	.028	1.94	1.37	1.14	.97	.86	.80	35.7	3.8
25	.0179	.0365	.026	1.70	1.18	.98	.85	.80	.74	38.4	2.9
26	.0159	.0461	.024	1.41	1.00	.82	.71	.68	.57	42.0	2.0
27	.0142	.0608	.022	1.18	.78	.68	.59	.52	.47	45.5	1.4
28	.0126	.0744	.021	1.04	.72	.60	.52	.47	.42	48.0	1.1
29	.0112	.0925	.020	.92	.65	.52	.46	.42	.38	50.0	.88
30	.0100	.1181	.018	.77	.54	.44	.38	.35	.31	54.6	.68

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Table 51

TABLE SHOWING CURRENT CARRYING CAPACITY OF DIFFERENT WIRES AT DIFFERENT DEPTHS OF WINDING, 1 SQ. IN. IN RADIATING SURFACE PER WATT.

B. & S. Gauge.	Diameter bare.	Resistance per foot 140° F.	Diameter D. C. C.	Amperes at different depths of winding layers.						Number of turns per inch.	13
				1	2	3	4	5	6		
4	.2043	.000283	.224	97.36	68.75	55.88	48.64	43.50	39.73	4.45	9428
5	.1819	.000357	.200	81.82	57.88	47.27	40.87	36.60	33.40	5.00	6720
6	.1620	.000450	.180	69.20	48.92	39.92	34.60	30.93	28.28	5.5	4800
7	.1413	.000567	.158	57.78	40.82	33.35	28.91	25.86	23.60	6.3	3344
8	.1285	.000715	.144	49.04	34.66	28.37	24.57	21.97	20.07	7.0	2416
9	.1144	.000902	.130	41.52	29.37	24.00	20.76	18.60	16.97	7.7	1728
10	.1019	.001137	.117	35.06	24.81	20.27	17.54	15.71	14.35	8.6	1233
11	.0907	.001436	.106	29.74	21.02	17.17	14.86	13.30	12.12	9.6	885
12	.0808	.00181	.093	24.79	17.52	14.31	12.40	11.09	10.09	10.7	615
13	.0719	.00228	.084	21.00	14.86	12.12	10.50	9.38	8.54	11.9	441
14	.0640	.00288	.075	17.66	12.49	10.19	8.83	7.88	7.21	13.3	312
15	.0570	.00362	.067	14.89	10.53	8.60	7.44	6.66	6.08	15.0	222
16	.0508	.00458	.059	12.40	8.77	7.21	6.20	5.56	5.09	17.0	154
17	.0452	.00575	.053	10.53	7.44	6.08	5.26	4.71	4.30	19.0	111
18	.0406	.00727	.048	8.88	6.28	5.12	4.44	3.97	3.63	21.0	79
19	.0358	.00916	.044	7.54	5.34	4.35	3.76	3.37	3.08	22.7	57
20	.0319	.01153	.040	6.49	4.58	3.74	3.24	2.89	2.64	25.0	42
21	.0284	.01454	.036	5.38	3.80	3.11	2.68	2.40	2.19	28.0	29
22	.0253	.01845	.033	4.58	3.24	2.64	2.28	2.04	1.87	30.3	21
23	.0225	.0231	.030	4.00	2.82	2.30	2.00	1.78	1.64	33.3	16
24	.0201	.0295	.028	3.37	2.38	1.94	1.67	1.51	1.37	35.7	11.4
25	.0179	.0365	.026	2.93	2.07	1.67	1.44	1.30	1.18	38.4	8.6
26	.0159	.0461	.024	2.49	1.76	1.44	1.22	1.09	1.00	42.0	6.2
27	.0142	.0603	.022	2.07	1.44	1.18	1.04	.94	.84	45.5	4.3
28	.0126	.0744	.021	1.78	1.26	1.04	.89	.78	.71	48.0	3.2
29	.0112	.0925	.020	1.61	1.14	.94	.79	.71	.65	50.0	2.6
30	.0100	.1181	.018	1.34	.95	.78	.64	.60	.55	56.0	1.8

siderably. Adding to any of these would tend to increase the E. M. F. of the armature, but not its capacity in amperes.

838. If the capacity of the armature is not sufficient, how do we proceed?

Ans. Take the next larger wire, or such a wire as will give the desired capacity, and from the diameter of this wire figure out a new armature. By using the same number of wires of a larger diameter, a greater cross-section of armature is obtained.

839. Do these considerations apply equally well, whether an armature is slotted, or not?

Ans. The only difference is that with a slotted armature it is necessary to take into consideration the length of the winding space in the slots only, not the total circumference of the armature. There is also considerable loss of flux through the teeth of the armature so that the flux must be assumed less. A great flux is obtainable, however, with the same field winding, as the magnetic circuit of a dynamo with a slotted armature has less resistance.

840. How do you proceed in the case of a slotted armature?

Ans. If we have an armature provided with slots of a fixed size we can but arrange to accommodate ourselves to it as best we may. It may be that the slots are of such size that the wire we have selected through our calculation will not fill out the slot well, and we must, therefore, try some other size wire. In this case it will be preferable to select a larger size wire if practicable. This had best be tried by actual experiment. As the wire often will not fill out the slot quite fully, calculations are not exactly reliable. Any deficiency can, of course, be made up by filling in with insu-

lation. The number of wires per slot is found by dividing the total number of wires by the number of slots.

841. How can the size of a slot capable of holding a certain number of wires be determined?

Ans. The approximate depth of the slot can be obtained by multiplying the diameter of the wire to be used by .86 and this by the number of layers placed over each other. The result will be exact if the wires lie as shown in Figure 512. The width of the slot can be found by multiplying the diameter of the wire by the number of turns per layer. It will be seen from the figure that each alternate layer will contain one turn less than the first.

842. Can slots be proportioned so that they will accommodate any number of wires?

Ans. The slots must be proportioned to the number of wires to be used, and the number of wires per slot must be carefully considered. If the number of turns per slot are few, the wires should be placed as shown in Figure 513. If there are many, according to Figure 512. Which of these two methods is to be used will have a bearing on the number of wires per slot. The total number must be a multiple of the number of layers.

843. After we have selected our wire, and determined the number of wires to be used, can we form some idea of what the losses in the armature will be?

Ans. We can easily figure the approximate loss of voltage in the armature from the size of wire to be used. To do this we first find from Table 50 the resistance per foot of the wire in question, and then measure the length of wire in one coil and multiply the resistance by the number of feet. If we have a bi-polar armature we again multiply this by half the number of coils (the two sides being in parallel). Since the loss in voltage is equal to the amperes

multiplied by the resistance, we need but to multiply the resistance so found by half the total current to find the loss in voltage that will occur. This loss is, of course, in direct proportion to the current. This loss is not of much importance in ring armatures, or in drum armatures either, when they are working with small currents, or on constant current work such as arc lighting; but with heavy, and variable currents it is a very important matter, and the lower the losses can be kept, the better.

844. Are there any special considerations to be borne in mind while winding the different coils?

Ans. It is quite important to see that each coil contains the same number of turns, and that these fill out the same relative space.

845. Why is this so important?

Ans. We have already seen that the two halves of the armature are generating in parallel, that is, the currents from the two sides meet at the positive brush and flow out to the line, and return by the negative side to the armature. If now there are fewer turns of wire on one side than on the other, or if there is one weak coil in the armature, one side or the other will always be generating a greater E. M. F. than the other and consequently current from the high pressure side will flow through the winding of the low side. To see this more clearly refer to Figure 514. On the armature there shown, there are 16 coils. If this armature is to generate 40 volts, each coil will be called upon to produce 5 volts. Now suppose one of the coils to be cut out of the circuit entirely. It is clear that at all times except when the dead coil is at the neutral points, there are 8 coils generating on one side against 7 on the other; i. e., 40 volts against 35. In order to find the current that would flow in such an armature while on open circuit, subtract the low

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voltage from the high, which leaves an active voltage of 5. If the resistance of the armature were .1 ohm a current of 50 amperes will be circulating a great part of the time.

846. Why would this not be a constant current?

Ans. For the reason that this current would be constantly changing in direction, because the strong side of the armature would be first on one side, and then on the other, of the fields. On open circuit a perfect armature would generate no current whatever; with an armature as described the current mentioned would always be flowing toward the coil which is cut dead.

The current would be changing in strength, because during the time the dead coil is short circuited by a brush it would be balanced by another coil under the opposite brush which for the moment is also dead. Consequently during that time the armature would not be generating at all.

847. How would this inequality of generation manifest itself if the dynamo were generating current?

Ans. If the dynamo were generating current this condition would greatly reduce its capacity. The current flows only in obedience to the pressure, and as this would be variable the current would of course also be variable.

848. Are differences in potential between different parts of an armature caused by any other conditions in the armature?

Ans. Such differences are sometimes caused by the location of the wires of different coils. Other things being equal the E. M. F. generated by any coil varies with its distance from the center of the armature. It can readily be seen that the farther a wire is from the center, the greater will be the area enclosed and therefore the greater the number of lines of force cut by it.

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849. What other cause is there for inequality of generation?

Ans. Another cause for inequality of generation between different coils lies in a difference of resistance.

850. Does this affect the generation on open circuit?

Ans. It does not. We have already seen that the loss in potential in any circuit is proportional to the current flowing, multiplied by resistance of the circuit in which it flows. Therefore the drop in potential in any coil is in proportion to the current being taken from it. If one coil therefore has a much higher resistance than the others its potential will fall much more, and the side of the armature on which it happens to be will be of lower E. M. F. than the other, and there will be the same tendency to a vacillating current as in the case of coils of uneven number of turns. The variations will, however, not be near so great, for an excessive current flow from the strong side will reduce the pressure on that side, and the checking of the current on the low side will raise the pressure there, so that a balance will be obtained without any great current flow. The main danger of introducing inequality in the resistance of the winding lies in the winding of the inside of the coil with Gramme ring armatures. The space for the winding at this point is necessarily of a different shape than that on the outside, and there are also the spokes of the armature to contend with.

851. How many methods of armature winding are in general use?

Ans. The methods of armature winding are very numerous. For the present we shall confine ourselves to the methods used with hand winding on cylinder armatures.

852. Which is the most simple of these windings?

Ans. The simplest one of these windings is that shown in Figure 534, and we shall take this one for the purpose of demonstration. It will be noticed that in this figure there are 12 slots in the armature and 6 commutator sections, indicated by the wires twisted together.

853. Is it necessary that this proportion of slots and armature coils exist?

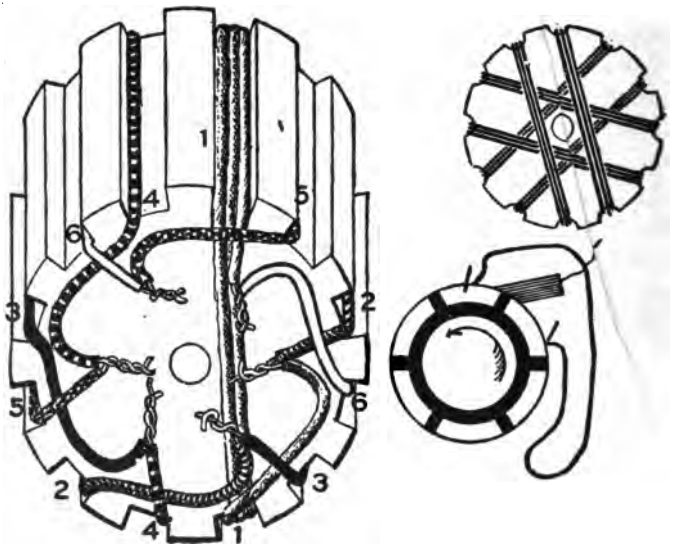

FIG. 534

Ans. It is not; in fact it is not at all desirable that this proportion should exist, but this proportion is very convenient for winding, as we shall see.

Begin winding by selecting two of the slots located opposite each other, as shown in the figure, and starting at 1 wind into those slots as many turns of wire as has been determined there should be and bring the last end of the

coil to the commutator section next the one from which we started.

854. Should this be to the one in front of, or behind the section from which the winding started?

Ans. This is immaterial. In actual practice there should not be any commutator sections in place while winding. They would be very much in the way. Instead, tie the two ends of the coil together and properly mark the beginning and end.

855. Are all coils wound in the same way?

Ans. They are; but in this case we must skip one slot at each subsequent coil, in order to make them come out right in the end. That is to say, if the first coil is wound into 1, 1, the second must be wound into 2, 2, the third into 3, 3, etc.

856. Why is this?

Ans. As each coil fills out two slots, we have with the third coil finished half of the armature. If we were to wind the slots in consecutive order, the connections for the commutator would all come on one side, and we could do nothing with the armature. As we now continue in the order we have started we finally complete the entire winding and have the beginning and end of one coil opposite each commutator section. We can now fasten the beginning of the first coil to its proper commutator section, and the end of it to the next one. It will be immaterial whether this be to the section ahead, or behind the starting section, but, whichever way we start, we must be sure to continue in the same way.

857. This being the most simple method of armature winding, why are not all armatures wound in this way?

Ans. The great objection to an armature wound in this way is that the coils become too large.

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858. Why are large coils objectionable?

Ans. In order to understand why large coils are objectionable we refer to the commutator shown at the right of Figure 534. Here a brush is shown bridging two commutator sections and short circuiting the coil connected to them. The coil indicated by the black line is the same one shown in the slots 1, 1, and the connections are identical. It can readily be seen that all of the coils will in turn become short circuited in the same way in the course of every revolution of the armature.

Now in the first place assume that the coil when thus short circuited is in an entirely dead part of the field. When a brush short circuits such a coil it takes all the current away from it. When the brush leaves the forward section of the commutator this short circuit must be broken, and current must be again established through the coil. As every coil possesses some inductance (which acts for an instant like a very high resistance), there is a tendency for the current in that half of the armature to jump across the insulation between the commutator sections, rather than pass through the coil. If this occurs there is destructive sparking. The greater the number of turns of wire in any coil, the greater will be the likelihood of this taking place.

859. Is this the main reason why the coils on an armature should be made up of few turns of wire?

Ans. It is not. The most important reason for this is the following: If the coil is not in an entirely "dead" part of the field there is always some current generated in it during the time the brush is in the position discussed above. This current circulates in the coil during the time the brush holds it on short circuit, without appearing in the outer circuit, and is therefore a dead loss. It furthermore

tends to heat the coils. Because two of the coils are nearly always on short circuit in this way, the loss and the heating are considerable when the coils are large. When these currents are broken by the commutator section sliding from under the brush, they also make themselves evident by severe sparking, if the coils are large.

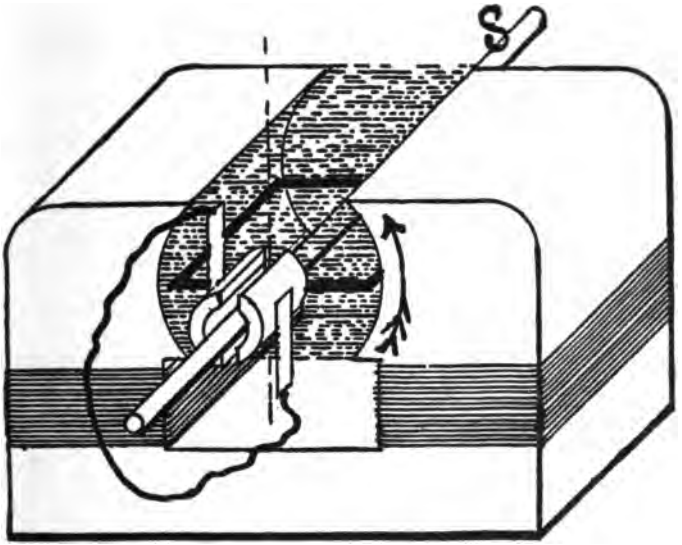

FIG. 535

860. Are there any more reasons why large coils are objectionable?

Ans. Another reason why large coils in an armature are objectionable can best be understood by reference to Fig. 535. A simple dynamo such as is depicted in this figure delivers a current graphically illustrated by Fig. 536. It will be seen that this is really an intermittent current. This is because the dynamo has but one coil, and while

this is at the neutral points, nothing is being generated. The current therefore fluctuates from 0 to its maximum. If we add one more coil the current line becomes as shown in Fig. 537, and the greater the number of coils the smaller becomes the percentage of non-generating coils, and the nearer does the current line approach a straight line showing a steady value.

861. Why cannot small coils be wound in the manner shown in Fig. 534.

Ans. It is desirable to make the coils as small as possible. The ideal coil would consist of only one turn. Now

FIG. 536

FIG. 537

as long as we wind only one coil into one slot we shall have the coils needlessly large. The number of coils is limited by the number of commutator sections, and unless we wind two coils into each slot (as we can see from Fig. 534) we can have but half as many commutator sections as there are slots. In order to get a small coil it is therefore necessary to get two coils into each slot.

862. Can this be done in more than one way?

Ans. This can be done according to any of the plans shown in Fig. 538. In this figure the black and white circles respectively represent the wires of the two different coils wound into the same slot.

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We have already seen under ring armatures, that wires of different coils should all be of the same distance from the center of the armature, so as to cut the same number of lines; it follows, therefore, that the plan showing one coil wound over the other should not be used where it can be avoided.

863. How do you manage to place two coils in one slot?

Ans. In order to understand exactly how this is done let us consult Fig. 539. This figure is a duplicate of Fig. 534 with the exception that now we have as many commutator sections as there are slots in the armature. The

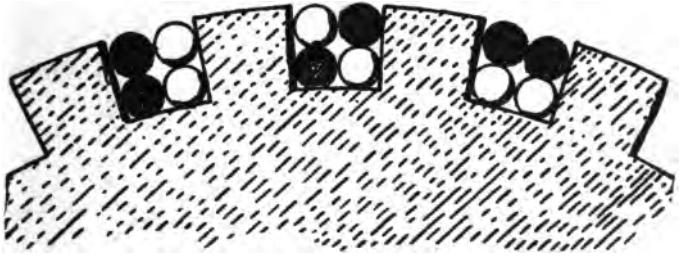

Fig. 538

black circles represent the wires of one set of coils, and the light those of the other.

The simplest method of winding two coils into one slot is, first to wind one coil complete, filling half the slot, then turn the armature half way round and wind the second coil over the first. As this, however, gives two coils of different lengths and resistance, and also cutting a different number of lines of force, such a winding is seldom used. A better way is the following: Cut two wires of sufficient length so that each will make one coil, place the armature upon two crossbars of convenient height so that it can be

easily turned over when required. Mark all of the slots with appropriate numbers according to the plan of wiring selected, so there may be no confusion when the work is started. A very good plan is shown in Fig. 534. This plan gives the smallest head of any because there are always two coils running parallel to each other across the ends of the armature. Thus we have three layers of coils

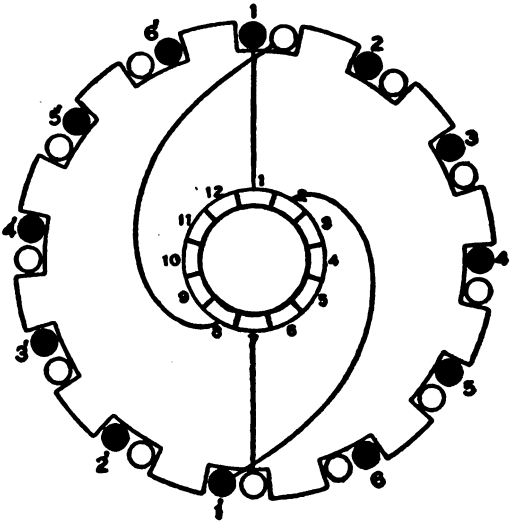

FIG. 539

crossing over each other, while with any of the others we should have six. But in order to get the advantage of this smaller head, we cannot wind the coils in the order given in the explanation of this winding. It becomes necessary to wind completely, at the same time, the two coils that are running parallel with each other across the ends. To do this requires more experience and forethought, than the way previously described.

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Begin the winding with the coil marked 1, and make one complete turn and fasten the two ends of the wire together temporarily if more turns are to follow, or fasten each to its proper place on the commutator, if there is to be but one turn. Now turn the armature half way round and wind the other wire in the same way. If there are to be more turns, continue to wind the second turn. After this is finished turn the armature back to its original position and wind the first wire again. Repeat in this manner until the desired number of turns in both coils have been obtained. By reference to Fig. 539 we note that the windings do not skip slots as in Fig. 534. This is easily explained when it is noticed that each slot contains two conductors and that at each step we skip one conductor as before.

It is not necessary in actual practice to turn the armature around as above suggested. This was suggested merely as a beginning to make the principle more plain. The same result can readily be obtained if the armature is left stationary. The windings need merely to be so arranged that they will come right for connection to the commutator as shown in the cut.

It is well enough to use care that all of the coils are wound in the same direction, but it will not materially affect the operation, if one part of the coils are wound left hand, and the others right hand. The essential point is to see that they are so connected that the magnetism resulting from a current flow through the coil will be the same in all. If it is different in one coil from the others it can easily be rectified by simply changing the end connections of the coil in question.

864. Are all armatures hand wound?

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Ans. Hand winding is customary with the smaller drum, and ring armatures only. It is the only method that can be used with ring armatures, and also with drum armatures where the wire is to encircle the whole armature. The larger dynamos are now made mostly multipolar, and in these the coils do not return at nearly, or wholly, diametrically opposite points as they do in those machines we have so far had under consideration. With multipolar machines the armature is divided into as many sections as there are poles. While it is possible to work any regularly

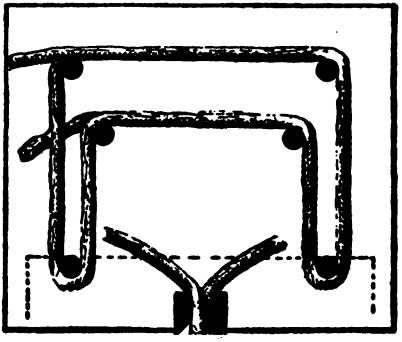

FIG. 540

wound drum, or ring armature in connection with many poles, it is not customary to do so. In general the coil wound on a multipolar armature has its return winding spaced about as far from the first turn, as it is from the center of one pole piece to the center of the next one.

865. How does this affect the winding?

Ans. This gives us a winding of much lower resistance than could otherwise be obtained, and the magnetic circuit is also much better. Furthermore, it makes possible the use of so-called "former coils."

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866. What is a former coil?

Ans. A former coil is one that is wound upon a former, i. e., one that is wound complete before it is placed upon the armature.

867. How are such coils made up?

Ans. Figs. 540 and 541 show two styles of former coils, and the manner in which they are wound. In Fig. 540 the black circles represent strong pins fastened into a piece of

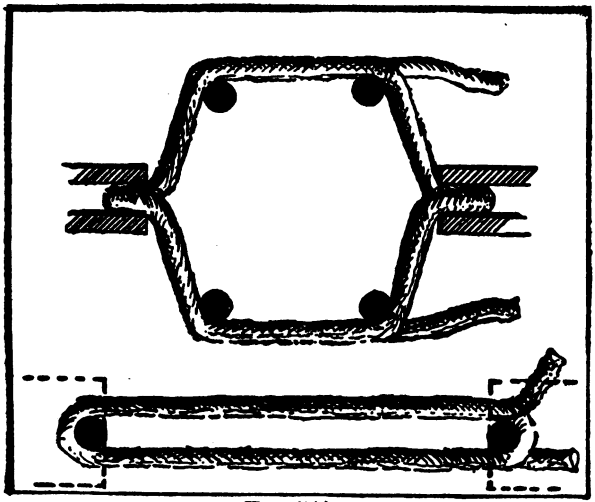

FIG. 541

plank, or other suitable material. The wire is wound around these pins as indicated in the figure, as many turns being taken as it has been decided to allow for each coil. When the coil is thus completely wound it is taken from the pins, and the lower ends placed in a suitable clamp, as indicated by the broken line in the lower center of the figure. After this clamp is fastened onto the coil the two halves of the coil are spread apart, one being pulled toward the operator and the other pushed away from him at

right angles to the clamp. In this way the coil is made to assume the shape illustrated in Fig. 542. Before winding a coil in this manner it is of course necessary to know exactly what length it must be, and a pattern coil must therefore first of all be prepared, from which the spacing of the pins can be taken, so that the completed coil will fit into the slots for which it is intended.

868. How are such coils placed upon the armature?

Ans. Begin placing the coils at any convenient slot, and lay them in, as indicated in Fig. 542. It is necessary to mark the beginning, and end of each coil, so that there may be no wrong connection when the wires are finally connected to the commutator.

FIG. 542

Before placing the coils the slots must of course be insulated as explained previously. We now continue to lay in coils until the whole armature is full, but when nearly full, the forward ends of the coils we are placing require to be brought under the first coils put in place. To do this it is merely necessary to raise up the first six coils, (in this case) and place the forward ends of the last six under them in the regular order.

869. By what name is this winding known?

Ans. This is known as the "evolute" winding. It will be noticed that when this winding is completed, the wires of the outer portion entirely conceal those of the inner, and thus give this style of winding its characteristic appearance.

870. What other manner of winding multipolar armatures is there?

Ans. Another method of forming coils is illustrated in Fig. 541. In this case the coil is first wound around two pins, as shown at the top of the figure. The ends are then placed in clamps, as indicated by the dotted lines at the top and shaded lines in the center of the figure. After these clamps are fastened, the coil is turned one-fourth around, and the wires spread over the four pins, as indicated in the figure.

871. How is this coil placed upon the armature?

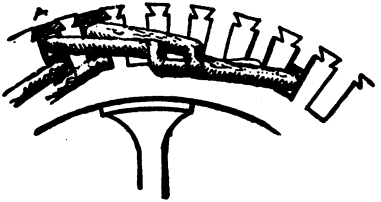

FIG. 543

Ans. The coil formed in the manner above assumes the shape shown in side view in Fig. 543 and is placed upon the armature as there indicated, the manner of placing being the same as that of the previous coil.

872. What name is given to this style of winding?

Ans. This is termed a "barrel" winding and its characteristic appearance can be seen from the figure.

873. Is it necessary to carry out the same kind of winding on both sides of an armature?

Ans. There is nothing to prevent one from using one of these windings on one side of the armature, and the other on the opposite side. They cannot, however, be combined on the same side. The windings of large machines very often are made up of bars of copper made of special

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sizes to suit. These are often arranged as shown in Figs. 544 and 545. Sometimes such bars are bare and laid into the slots with insulation loose on the sides and bottom and between the different bars of a slot. Such winding is often held in place by pieces of wood inserted into the slots as indicated in Fig. 543, the slots being specially prepared to admit of this. Where no such provision has been made the wires are held in place by the usual binding wires.

874. Is there any difference between the armature of motors and dynamos?

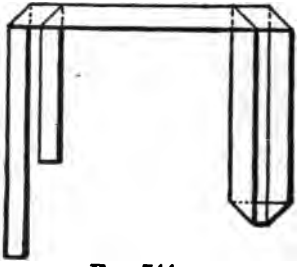

FIG. 544

MOTOR ARMATURES.

Ans. Theoretically there is no difference between the armature of a dynamo and motor. In fact, many machines are placed in conditions in which their functions change, perhaps a hundred times per day, from that of generator to that of motor.

875. Are there any special provisions necessary to make them operate thus?

Ans. No. This change takes place automatically, and the operation is so smooth that the observer will have no idea in which capacity the machine may be operating from moment to moment. It is also no unusual thing for a dynamo working in parallel with other generators to be-

come reversed, and instead of delivering current to the line, it will be drawing from it and running as a motor.

876. What should one principally have in view in the design of a motor armature?

Ans. Motor armatures must be designed to produce a certain counter E. M. F. just as dynamo armatures are designed to produce E. M. F. In the case of a dynamo the power is measured by the product of the E. M. F. and the current, so in the motor the power is proportional to the product of the counter E. M. F. and the current.

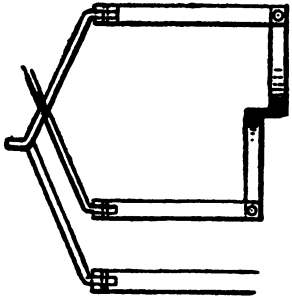

FIG. 545

877. How do you proceed to calculate the winding for a motor armature?

Ans. In the same way as with a dynamo except that the E. M. F. should not be figured as high. The current passing through a D. C. motor equals $\frac{V-v}{R}$, where V is the volume of the line that supplies it; v the counter E. M. F. of the armature, and R its resistance. It is apparent that in order to get more power out of a given motor, its counter E. M. F. must be reduced in order that a greater current can flow.

878. How is this brought about?

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Ans. With a motor in operation this counter E. M. F. is reduced when the speed reduces, on account of a heavier load. More current is thus allowed to flow until the power of the motor becomes equal to the work required of it, but if the load exceeds the capacity of the motor it will take too much current, and burn out the armature. If a motor is to be designed to operate at a certain speed, all of these facts must be taken into consideration, and the wires so selected that when running at the required speed, the necessary counter E. M. F. will be generated.

For illustration, take the same armature that was considered in the previous section. In this case a No. 12 wire was required. This gave 11 turns per inch, and its carrying capacity was 14.3 amperes. The dimensions of the armature were 8″x8″, requiring about 770 feet of wire. With this quantity of No. 12 the resistance is 1.39 ohms.

Only one-half of this, however, is on one side, and only 14.3 amperes pass on one side, so that the total E. M. F. to drive this current through the armature is $14.3 \times .697$, which is 9.96. In order that this motor may allow the 14.3 amperes to pass, its counter E. M. F. must fall to 9.96 volts less than the E. M. F. of the line. If this is 110, the speed must slack off about 9 per cent in order that the motor may develop its full power.

It is easily seen from this that, in order that the motor may operate at a fairly constant speed, the resistance of the armature should be made as low as possible. In practice it is generally made so low that a reduction of 1 per cent in speed wll bring about the required lowering of counter E. M. F. to cause the proper current to flow.

879. How do armature troubles manifest themselves?

Ans. Either by excessive sparking at the commutator, or by abnormal heating of the armature.

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880. What are the causes of such troubles?

Ans. They may result from any one of the following causes: There may be a wrong connection of one, or more of the coils. Some of the coils may be grounded. There may be an open circuit. There may be a short circuit. The brushes may be improperly set. The brushes may not make sufficient contact with the commutator. The commutator may be rough or worn. The fields may be of uneven strength.

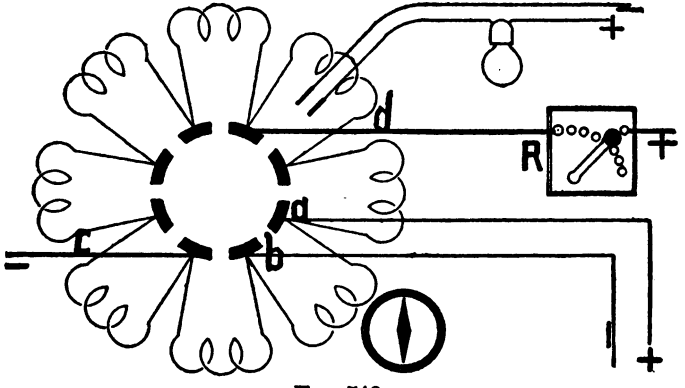

FIG. 546

881. How can a wrong connection of the coils be tested for?

Ans. In order to see how this test can be made let us consider Fig. 546 for a moment. This figure shows the wiring of an armature connected to the commutator segments exactly as it would be if it were taken off, and the coils separated without detaching from the commutator, instead of being placed in an orderly manner upon the core of the armature. In other words, the connections are exactly as in an armature. If we should now take the two

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wires of some supply of current capable of delivering a few amperes, and connect these two wires to two adjacent commutator segments, as shown at *a*, and *b*, it is clear that current would flow through the coil connected between these two sections, and also through the other coils. The current has two paths: one through the single coil, the other through the remaining seven coils in series.

The current in the two coils flows in opposite directions, with the result that a field of force is set up in the vicinity of the single coil. A suitable galvanometer placed at this point will be deflected in a certain direction. By revolving the armature and applying the test to each succeeding pair of commutator sections, a number of deflections of the needle will be obtained.

If all the coils are correctly connected these deflections will all be in the same direction. If one of the coils is connected wrong, a different deflection will be obtained. If one of the coils has been wound on in the wrong direction, it is not necessary to rewind it; the connections can simply be reversed.

882. What is meant by a "ground"?

Ans. An electrical connection between some current carrying part of the armature, and the metal armature frame. A "ground" is often caused by the insulating covering of the wire breaking down, thus allowing the wire to come in contact with the iron core.

883. How do you test for this condition?

Ans. The simplest method of testing for a ground consists in taking a lamp or voltmeter and connecting it as shown in Fig. 546. Place one of the wires in contact with the iron core, and the other in contact with the wire on the armature. If the lamp lights, there is a connection between the wire and the core, and this should be removed.

884. How is an open circuit located?

Ans. Referring to Fig. 546, connect the commutator as shown by the horizontal lines *c. d.* to some source of supply. A rheostat is needed to adjust the current strength until a suitable deflection of the needle is obtained between adjacent commutator segments. Now, take two wires of the voltmeter and test the voltage between the various adjacent commutator segments. A reading will be obtained between each two segments on one side of the commutator, but on the side which contains the open coil no reading will be obtained until connection is made between the two segments to which the open coil is connected. At this point the voltmeter will show practically the full voltage of the supply current.

885. How do you locate a short circuit?

Ans. If the short circuit has come on while the armature was in use, it will locate itself by a burned out coil. To test a new armature for short circuits we can proceed in the same way as for open circuit, the only difference being that, when we come to the short-circuited coil, we shall obtain either none, or at least a reduced deflection.

886. What effect does an improper location of the brushes have?

Ans. An improper location of the brushes will manifest itself by a more or less severe sparking. If the brushes are of the right dimensions the trouble can be remedied by simply shifting them to the proper location, which is that of least sparking. Brushes should be of such length, and set at such an angle, that they come in contact with diametrically opposite points on the commutator, with all bi-polar machines.

887. How must the brushes be set in connection with multipolar machines?

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Ans. This depends on the manner in which the armature is wound. With a lap winding there are as many brushes as there are pole pieces, and they must be equally spaced around the periphery of the commutator. Provision must also be made so that they can be shifted to the point of least sparking. In wave wound armatures there may be only two brushes, these being so spaced that they are separated by an angle equal to the angle of separation of two adjacent pole pieces; for instance, with a four-pole field they would be separated by an angle of 90°.

888. Is much shifting of the brushes necessary?

Ans. This depends very much on the design of the machine. With some of the older machines constant shifting of the brushes is required with changes in the load, but with the newer, and better machines this is reduced to a minimum.

889. What is the ordinary size of a carbon brush?

Ans. It should be of such size that not more than 25 to 40 amperes per square inch of carbon are ever required to flow through it.

890. How does inequality in field strength affect an armature?

Ans. Wherever this exists there will be more lines of force cut by the armature on one side than on the other, thus causing a higher potential to be generated on one side than on the other. The brushes will have to be set uneven distances apart around the commutator, and useless currents will be set up in the armature windings, which will not only cause a loss of power, but which will tend to overheat the armature.

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Transformers

891. What is the function of a transformer?

Ans. To transform the current from a higher, to a lower voltage, or vice-versa.

892. What principles govern the action of a transformer?

Ans. The principles of electro-magnetic induction.

893. What is a step up transformer?

Ans. A transformer that raises the voltage.

894. What is a step down transformer?

Ans. One that lowers the voltage.

895. How are transformers cooled?

Ans. Small sizes by surface radiation. Larger sizes by oil; also by air blast. Some of the smaller sizes are cooled by water circulating through surrounding coils.

896. How is direct current transformed from one voltage to another?

Ans. By means of a machine called a motor-generator.

897. Describe in brief a motor-generator.

Ans. It consists usually of a D. C. motor driven by current at the voltage of the incoming line. This motor in turn drives a D. C. generator that furnishes current at the desired voltage.

898. How is the outgoing voltage regulated?

Ans. By altering the field strength of the generator.

899. In case the incoming and outgoing current can bear the same ratio to each other constantly, what kind of an apparatus is used?

Ans. A machine called a dynamotor.

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900. Describe the operation of a dynamotor.

Ans. It is a D. C. motor running on the incoming voltages. On the same armature core is a separate winding connected to its own commutator at the other end of the armature. One set of field magnets serves for the motor winding and the generator or dynamo winding.

901. Describe in general terms a rotary converter.

Ans. It combines in a single machine the functions of a motor-generator, and a dynamotor.

902. Why are rotary converters and transformers necessary?

Ans. Because it is more economical to transmit alternating current at high voltages and transform, or convert it to the lower voltage at which it is used.

903. Give another reason for using rotary converters.

Ans. For the purpose of transforming alternating current into direct current when direct current is used.

904. What is the chief point of difference between a rotary converter and a direct current generator?

Ans. The rotary has collector rings connected to certain points of the armature winding.

905. What governs the number of such connections?

Ans. The number of poles and phases.

906. Describe the different types of rotaries.

Ans. They are built for single-phase, two-phase, three-phase or six-phase.

907. How many collecting rings has a two-phase converter?

Ans. Four collecting rings.

908. How many collecting rings has a three-phase converter?

Ans. Three collecting rings.

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909. When alternating current is transmitted at high pressure, what means are employed for lowering the potential?

Ans. Transformers.

910. When the incoming current is direct and the outgoing current alternating, how is the voltage raised?

Ans. By step up transformers.

911. Describe the winding of a rotary converter.

Ans. It is usually shunt wound, or compound wound, although sometimes separately excited.

912. How are rotaries in railway service usually wound?

Ans. Compound, owing to variations in the load.

913. What advantage is gained by this method of winding?

Ans. It tends to maintain the D. C. voltage constant.

914. Upon what does the ratio between the A. C. and D. C. voltages of a rotary depend?

Ans. Upon the number of phases, the lead given the D. C. brushes, the wave form of its alternating current, and upon the field excitation.

915. Does the armature drop affect this ratio to any extent?

Ans. It does by decreasing it slightly when running A. C. to D. C. and increasing it when running D. C. to A. C.

916. What are the ratios of conversion approximately?

Ans.

Single-phase	.71
Two-phase	.71
Three-phase	.61
Six-phase	.71 or .61

917. Give an example illustrating above.

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Ans. If D. C. voltage is 550 volts, the A. C., if two-phase will be $500 \times .71 = 390$ volts, or if three-phase it will be $550 \times .61 = 335$ volts.

918. What precautions should be observed in the erection of a rotary converter?

Ans. First—It should be protected from moisture. Second—It should be protected from dust or dirt. Third—It should be in a well ventilated room and kept as cool as possible.

919. Should the frame of the machine be insulated?

Ans. Generally speaking the strain on the winding insulation will be decreased, and danger to attendant increased by insulating the frame.

920. If a rotary has been exposed to dampness how may it be dried out?

Ans. By running it with about 10 per cent of the normal A. C. voltage, while at same time observing certain precautions noted in the text of this book under head of rotary converters.

921. What method should be pursued in caring for the commutator?

Ans. Wipe it off with a piece of canvas—never use waste. Lubricate it with a very small quantity of vaseline, or oil applied with a piece of cloth. See that none of the segments is at all loose.

If it gets out of true turn it down.

922. If a commutator gets hot while carrying only a normal load what should be done?

Ans. Heating under such conditions is an indication that the commutator is worn out, and should be replaced by a new one.

923. Give some of the causes of sparking at the brushes.

Ans. Brushes may not have proper lead.
Brushes may not fit commutator.
Brushes may be burned on end.
Commutator surface may be rough.

924. What is meant by a rotary bucking?

Ans. When arcing occurs between two adjacent brush holder arms, thus short circuiting the machine.

925. Name a few of the principal causes of bucking.

Ans. Rough or dirty commutator.
Excessive voltage.
Fluctuations in the voltage.

926. What is an oscillator, and what is its function?

Ans. An oscillator is a device operated either magnetically, or by mechanical means, and its function is to produce a slight, periodic movement of the armature shaft endwise.

927. Why is this endwise movement of the shaft necessary?

Ans. In order to prevent the wearing of grooves in the commutator.

928. What is meant by the hunting of a rotary converter?

Ans. It is a slight change of the speed of the armature.

929. What is the cause of hunting?

Ans. Irregularities in the speed of the generator delivering current to the rotary, thus causing a slight difference in the relative positions of the armature of the two machines, resulting in a change in the phase positions of the generator E. M. F. and the counter E. M. F. of the converter.

930. What are the usual methods of starting rotary converters?

Ans. First—By a separate A. C. starting motor.

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Second—By applying direct current to the commutator. This starts the converter as a shunt motor.

Third—By applying alternating current directly to the collector rings. This starts the converter as an induction motor.

931. What is meant by synchronizing a rotary converter?

Ans. Bringing it to the same frequency, the same phase, and the same voltage as the generator from which it is receiving current.

932. What method is employed to determine when the machines are in synchronism?

Ans. There are several methods, the most common one being by means of incandescent lamps connected in series with the two machines.

933. What is a synchroscope?

Ans. It is an instrument for determining when electrical machines are in synchronism.

934. What is an automatic synchronizer?

Ans. It is a device that will automatically synchronize two electrical machines; also connect a synchronized machine with the main by means of an electrically operated switch.

935. Name two important points to be looked after before starting a rotary converter.

Ans. First—See that both the A. C. and D. C. brushes are properly adjusted and that every thing is clear about the converter. Second—See that the switches on board are open on both the A. C. and D. C. sides, and that the resistance of the rheostat is all cut in the field circuit.

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Switch Boards

935. How are switchboards made up?

Ans. They are built up of panels of slate or marble supported by frames of angle iron.

936. How are the different panels designated?

Ans. Some are for motor control, others for dynamo running, others for operating the outer circuit, and others for charging storage batteries.

937. Is a knowledge of switchboards an important matter?

Ans. It is, and every engineer should especially study those in his own station.

938. What is the regular equipment of a D. C. switchboard having a capacity of from 250 to 6,500 amperes?

Ans. One carbon-break or magnetic blow-out circuit breaker with telltale.

One illuminated dial ammeter with shunt.

One hand wheel and chain for operating rheostat.

One receptacle for voltmeter plug.

One S. P. S. T. field switch.

One S. P. S. T. main switch.

One recording watt-hour meter.

939. What is meant by the abbreviations S. P. S. T.?

Ans. Single Pole Single Throw.

940. What does D. P. D. T. mean in speaking of switchboards?

Ans. Double Pole Double Throw.

941. What is meant by T. P.?

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Ans. Triple pole. It opens every circuit of a three-phase system.

942. Is it good practice to place a main switch at the machine?

Ans. It is best.

943. Why?

Ans. So that the cables from generator to board may be cut off at the generator.

944. What is an equalizer?

Ans. It is a cable running along from machine to machine, and connecting the functions of series field and brush on all the machines, but does not connect with switchboard.

945. What kind of a break has the field switch?

Ans. A carbon break.

946. Describe the action of a field switch.

Ans. Just before it opens it makes contact with an extra clip, and puts a resistance on as a shunt around the field coils.

947. If this were not done what would be the consequences?

Ans. The fields would act as a spark-coil and the insulation be damaged.

948. When it is desired to throw a generator in parallel with other generators already running what is the proper method of procedure?

Ans. First. Close main and equalizer switches near the machine.

Second. Close field switch on panel.

Third. Close circuit breaker.

Fourth. Insert potential plug in receptacle and regulate voltage.

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Fifth. When proper voltage is obtained close the other main switch on panel.

949. What is meant by voltage?

Ans. Electric pressure, or potential.

950. What is a volt?

Ans. The unit of pressure.

951. What is a voltmeter?

Ans. An instrument that indicates the voltage.

952. What is an ohm?

Ans. The unit of resistance.

953. Give a brief definition of Ohm's law?

Ans. The electromotive force equals the resistance multiplied by current intensity.

954. What is an ampere?

Ans. It is the unit of volume, or quantity-time unit for measuring the rate of flow of an electric current.

955. What is a coulomb?

Ans. It is an ampere-second. A coulomb equals the flow of an ampere of current past a given point each second of time.

956. What is an ammeter?

Ans. An apparatus for measuring current rate.

957. What is the meaning of the word watt as used in electrical work?

Ans. A watt is the unit of work. It equals volts$\times$amperes.

958. What is the function of the wattmeter?

Ans. To record the watt-hours of work.

959. What is a kilo watt (K. W.)?

Ans. 1,000 watts.

960. Expressed in horse-power, what is one K. W. equal to?

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Ans. 746 horse-power.

961. What is a field rheostat?

Ans. An apparatus for controlling the current output.

962. What is the function of a transformer?

Ans. To transform the current from a higher to a lower voltage, or from A. C. to D. C.

963. What is meant by synchronism of electric machines?

Ans. When the maximum value of the E. M. F. in each machine occurs at exactly the same instant of time, the machines are in synchronism.

964. What is meant by the exciter panel of a switchboard?

Ans. It is the panel that is equipped with the necessary switches, etc., for connecting the small exciter dynamo with the other generators in the station.

965. What is a sub-station?

Ans. It is the connecting link between the transmission line, and the trolley wire or third rail.

966. When A. C. is generated at the power station, and D. C. is used on the line, how is it accomplished?

Ans. The A. C. is changed to D. C. by rotary converters at the sub-station.

967. What is meant by frequency?

Ans. The number of times the current reverses per second.

968. What is the usual frequency for railway motors?

Ans. 25 is the standard.

969. What is a frequency changer?

Ans. A machine which receives current at one frequency and delivers it at another frequency.

970. What apparatus is used in an A. C. to D. C. sub-station?

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Ans. Step down transformers, rotary converters, and A. C. incoming and D. C. outgoing switchboards.

971. What is the proper procedure for placing rotary converters in service?

Ans. After the machine has been started from the A. C. ends, and builds up with the proper polarity, first close the equalizer switch (on machine)—second, close circuit breaker on panel—third, insert potential plug in receptacle and regulate voltage—fourth, when the proper voltage is obtained, close positive switch (on panel).

972. What will be the result if the rotary builds up with polarity reversed?

Ans. The voltmeter will swing back of zero.

973. How may the polarity be corrected?

Ans. By means of the four-pole, double-throw field break-up reversing switch mounted on the converter.

974. Describe an oil switch.

Ans. It is a switch similar in its action to other switches, with the exception that its mechanism is immersed in a small tank of oil.

975. What advantage is gained thereby?

Ans. Reliability of action in opening or closing a circuit.

976. Mention another advantage gained by the use of the oil switch and oil circuit breaker.

Ans. It has made safely possible the transmission and use of high-tension currents of electricity.

977. What is a circuit breaker?

Ans. It is a switch so designed as to be capable of frequently opening the circuit carrying its full current without any damage to itself.

978. What is a galvanometer?

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Ans. An instrument consisting of a coil of wire carrying the current to be tested, and a magnet, the two being arranged so that one can be deflected.

979. Describe the Thompson type of galvanometer.

Ans. The coil of wire is stationary, and the light magnetic needle is suspended by a silk thread.

980. What is a lightning discharge?

Ans. An equalization of potential between the earth, and either clouds, or saturated atmosphere.

981. What path does the discharge generally follow?

Ans. The path of least resistance.

982. What are the general requirements for protection of electric stations from lightning?

Ans. The supplying of paths to ground for any charge which might accumulate on lines or machinery.

983. What is the general theory of the multi-gap lightning arrester?

Ans. When voltage is applied across a series of multigap cylinders, the voltage distribution is not uniform, but is governed by the capacity of the cylinders, both between themselves, and also to ground, which results in the concentration of voltage across those gaps nearest the line.

984. What are the principal elements of a 600 volt D. C. aluminum lightning arrester?

Ans. Two concentric aluminum plates immersed in an electrolyte contained in a glass jar, the outside plate of each cell being positive, and the inner one negative.

985. Describe the multigap lightning arrester for A. C.

Ans. It consists of a series of spark gaps shunted by graded resistances, but without series resistance.

986. Describe briefly the aluminum lightning arrester.

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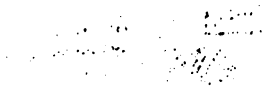
Ans. It consists of two aluminum plates on which has been formed a film of hydroxide of aluminum, immersed in a suitable electrolyte.

987. Describe the D'Arsonval galvanometer.

Ans. In this type the small light coil of wire is suspended by a fine bronze wire between the poles of a stationary magnet.

988. How are the readings taken from these instruments?

Ans. From a circular scale, over which the needle of the instrument swings.



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Definitions

A

A. C.—Alternating Current.

Absorption.—The act of one form of matter sucking, or draining in some other form of matter, as in the case of a sponge taking up water.

Acceleration.—The increase of motion.

Accumulated Electricity.—Electricity confined or stored, as in a condenser.

Accumulator.—Sometimes used to designate a condenser, a Leyden jar, or a storage battery.

Active Coil.—A coil or conductor conveying a current of electricity.

Active Current.—The active constituent of an alternating current, in contradistinction from the wattless component.

Active Wire.—The section of wire on the armature of a dynamo which goes through the field of force, in contradistinction from the remaining wire, which does not pass through the flux.

Aerial Circuit.—An elevated circuit.

Air Blast.—A blast of air acting upon the surface of a commutator to prevent damaging flashes. Also used to cool transformers in some cases.

Air Gap.—Any gap or aperture in a circuit which contains air only.

Air Insulation.—Insulation produced by the action of air.

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American Wire Gauge.—The name by which the Brown & Sharpe wire gauge is known, in which the diameter of the largest wire, No. 0000, is 0.46 inches, and wire No. 36, 0.005 inches, and all other diameters progress in geometrical order.

Ammeter.—An abbreviation for ampere meter. Used for measuring current rate, or volume. Any calibrated galvanometer having its scale marked to read amperes is an ammeter.

Ampere.—The unit of electric current flow. An ampere is that volume of current which would pass through a circuit that offered a resistance of one ohm under an electromotive force of one volt.

Ampere Hour.—A unit of quantity equal to the amount of electricity transmitted by one ampere flowing during one hour.

Ampere Turn.—A unit of magneto-motive force equal to the force resulting from the passing of one ampere over a single turn of wire.

Anode.—The positive pole a battery.

Arc.—A segment of a circle. A voltaic arc.

Armature Reaction.—The reactive magnetic effect resulting from the action of the current in the armature of a dynamo on the magnetic circuit of the machine.

B

B. S. G.—British standard gauge.

B. & S. W. G.—Brown & Sharpe wire gauge.

B. W. G.—Birmingham wire gauge.

Balanced Load.—A load uniformly apportioned to two or more generators.

Balanced Resistance.—A resistance arranged in a bridge, and balanced by the residuary resistance in the bridge.

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Bar Windings.—Armature windings constructed of copper bars.

Bipolar.—Possessing two poles.

Birmingham Wire Gauge.—A wire gauge used in England.

Booster.—An auxiliary dynamo used to increase the voltage of a feeder, or a set of feeders beyond the voltage of the rest of the system.

Bridge, Electric.—A contrivance used to measure unknown resistances by comparison with adjustable ones.

Bunched Cable.—A cable having more than one wire, or conductor.

Bus-bars.—Bars composed of heavy conducting metal, and connected directly with the poles of generators.

C

C. G. S.—Centimetre, Gramme, second.

C. P.—Candle power.

Calibrate.—To ascertain the complete or relative values of the indications of electrical measuring instruments.

Candle.—The unit of photometric energy. Equals the light produced by a standard candle burning at the rate of two grains per minute.

Cathode.—Opposed to anode.

Condenser.—A device for augmenting the capacity of an insulated conductor by placing it in contiguity to another earth-connected conductor, but from which it is separated by an intervening body which will permit electrostatic induction to occur through it.

Constant Current.—A current, the strength of which does not vary.

Continuous Current.—A current flowing in the same direction only.

Cycle of Alternations.—Alternations of the current per second.

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Coulomb.—The unit of electric quantity accepted for practice. That quantity of electricity that would pass in one second through a circuit conveying one ampere. That quantity of electricity contained in a condenser of one Farad capacity when subjected to an E. M. F. of one volt.

D.

D. C.—Direct current.

D. P. S.—Double pole switch.

Differential Winding.—Double winding of magnet coils resulting in the opposition of the two poles to each other.

Dynamic Electricity.—Current electricity as distinguished from static electricity.

Dyne.—The C. G. S. unit of force.

E

E. H. P.—Electrical horse-power.

E. M. F.—Electromotive force.

Electrolysis.—Chemical decomposition by the action of an electric current.

F

Farad.—The practical unit of electrical capacity. That capacity of a conductor that is capable of holding one coulomb at one volt potential.

Feeders.—Wires furnishing the main conductors with currents at different points, thus serving to equalize the potential under load.

Five-wire System.—A system wherein four series connected dynamos are connected to five conductors.

Flux.—Magnetic induction; the number of lines of force which pass through a magnetic circuit.

Frequency.—Number of cycles per unit of time by an alternating current.

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G

Gramme.—A unit of weight equal to the weight of one cubic centimetre of pure water at its maximum density, at a temperature of 39.2° Fahr. in a vacuum. A weight equal to 15.44 grains troy.

H

H. P.—Horse-power.

Hard-drawn Copper Wire.—Copper wire hardened without annealing, by being drawn several times.

Henry.—The practical unit of electro-magnetic, or magnetic inductance.

Horse-power, Electric.—A rate of electrical work equal to 746 watts, or 746 volt-coulombs per second.

Hysteresis.—Slowness of magnetization in respect to magnetizing force.

I

Induction.—The influence exerted without contact, by a magnetic field, or a charged mass upon neighboring bodies.

Inverted Arc Lamp.—An arc lamp wherein the positive carbon is below instead of above, as in the regular arc lamp.

J

Jump Spark.—A disruptive spark excited between two conductors, in distinction from a spark excited by a rubbing contact.

K

K. W.—Kilowatt.

Kilowatt.—One thousand watts.

Kilowatt-Hour.—Work equal to the expenditure of one K. W. in one hour.

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L

Lag.—Dropping behind.

Lagging of Current.—The retarding in phase of an alternating current behind the pressure which produces it.

M

Megohm.—One million ohms.

Metre.—A measure of length equal to 39.368 inches.

Micro-Fard.—The millionth of a Farad.

Mil.—One thousandth of an inch.

Multiphase.—Containing more than one phase.

Multiple Circuit.—A circuit in which the positive poles of a number of separate sources, and receptive devices are connected to a single positive lead or conductor; their negative poles being connected to a single negative lead or conductor.

Multiple Series.—Series groups connected in multiple.

O

Ohm.—The practical unit of resistance. A resistance that would confine the electric flow under an electromotive force of one volt to a current of one ampere, or one coulomb per second.

Ohm's Law.—The basic law, expressing the relation between current, E. M. F., and resistance in active circuits. Expressed algebraically $I=\frac{E}{R}$, in which I equals current intensity, E equals E. M. F., and R equals resistance. Other forms of expressing ohms law are as follows:

$$R=\frac{E}{I}. \quad E=RI.$$

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Over Compounded.—Compound winding of such a character on a dynamo that its voltage at its terminals is caused to increase under a greater load.

P

Parallel Circuit.—A term signifying multiple circuit.

Parallel Series.—Signifies a multiple series connection.

Periodicity of Alternation.—The rate of succession of alternations per second, or per minute. The frequency.

Polyphase Current.—Currents that constantly differ from each other, due to their proportion of periods of alternation, and adapted to polyphase motors.

Proposed Definition for 2,000 Candle Power.—An arc whose maintenance will require 450 watts.

R

Rheostat.—Will adjust the resistance without opening the circuit.

S

Standard Ohm.—A piece of pure copper wire one circular mil in diameter, and one foot long at a certain temperature.

Static Electricity.—Electricity generated by friction.

V

Volt.—The practical unit of electromotive force. An E. M. F. that would cause a current of one ampere to flow through a resistance of one ohm.

W

Water Horse-Power.—The power developed by 15 cubic feet of water falling through a distance of one foot per second.

Watt.—The practical unit of electric activity, rate of work, or energy. A watt equals 44.25 foot pounds of work done per minute, or 0.7375 foot-pounds of work done per second.

Watt-Hour.—Unit of electric work. One watt exerted or expended for one hour.

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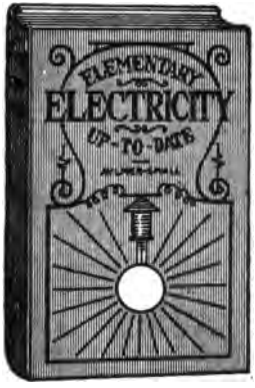

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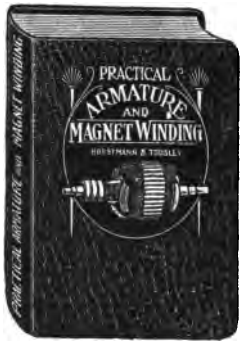

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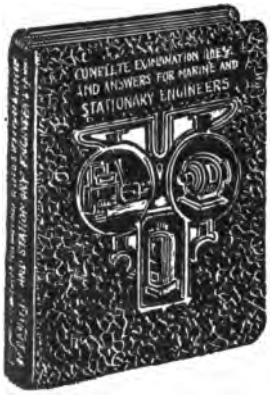

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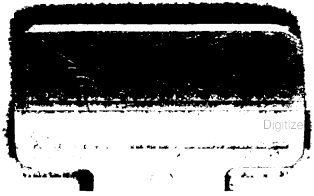

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